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Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

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The Effects of 2,4–D and 2,4,5–T Applications on the Stand Density of Canada Thistle *(Cirsium arvense Scop.)*[1]

LOWELL W. RASMUSSEN[2]

CANADA thistle has been considered a serious weed to agriculture in the northern parts of this country since its introduction. The plant characteristics and growth habits are described by Detmers (3) and Rogers (5) who also point out the seriousness of this weed to agriculture.

Early efforts to control Canada thistle were largely based on repeated removal of top growth as a means of starving the roots, (2, 4, 5, 6). The application of soil-sterilant chemicals was also used in early tests (1, 4, 5, 6). Both of these methods of control proved effective, but crop production was prevented on the infested area for one to several years.

The development and use of growth regulator types of herbicides, which are somewhat specific for certain species of plants, opened up new possibilities of weed control. Consequently, more recent studies have been undertaken to determine the effectiveness of these newer herbicides. Experimental tests were initiated at Pullman, Washington in the spring of 1948 to determine the effect of two herbicides, 2,4–D (2,4–dichlorophenoxyacetic acid) and 2,4,5–T (2,4,5–trichlorophenoxyacetic acid), on the stand density of Canada thistle and at the same time to determine the relative relationships of rates and times of application of the herbicides.

MATERIALS AND METHODS. In the spring of 1948, 144 plots each 15 × 20 feet were staked out in a uniformly infested Canada thistle area 120 × 360 feet in size. An eight- to ten-inch strip of sodium chlorate was applied along each plot border. The area was in a wheat field in which cropping was discontinued in 1947 because of the dense thistle stand. The test area was located on the lower part of a south slope on Palouse silty clay loam. The annual precipitation for the area is around 21 inches.

The treatments included 2,4–D isopropyl ester and 2,4,5–T isopropyl ester each at 1.2, 2.4, and 3.6 pounds acid equivalent per acre applied at bud, bloom, and mature stages of plant growth. These treatments were arranged in 2 × 3 × 3 factorial and randomized in each of eight replicates.

[1]Scientific Paper No. 1465, Wash. Agr. Exp. Sta., Pullman.

[2]Assist. Director Agr. Exp. Sta. formerly Agronomist (Weed Research)

The herbicides were applied with a hydropneumatic sprayer at a constant pressure of 30 p.s.i. and at a volume of 72 gallons per acre. A flat fan-type nozzle was used. The first year's applications were made with a single-nozzle hand boom. Subsequent applications were made with a four-nozzle boom. The treatments were applied once a year in 1948, 1949, 1950 and 1951.

Stand densities were measured by a length-line-transect method. A 20-foot light weight chain was maked off in 6-inch intervals. The chain was extended across each plot twice from opposite corners diagonally, and the number of inches of line contacting or covering Canada thistle growth was recorded. The transect measurements of stand were taken when the thistle shoots were eight to ten inches tall; May 15 to June 5.

Stand density was measured on each plot in the early summer of 1950, 1951 and 1952. Preliminary checks in 1949 indicated no measurable effect of the first year's treatment.

RESULTS AND DISCUSSION. After two year's applications of 2,4–D and 2,4,5–T, some thinning of the thistle stand was evident. The line-transect measures of stand were taken in early June 1950. The treatment means are summarized in Table 1. A plot having a solid ground cover of thistle plants would have a stand cover value of 480. The line-transect method of stand measurement was found to be most effectively used on plants not over ten inches tall. Therefore, plots showing values of around 175 or more were found later to be completely covered by thistle plants.

Table 1. Stand of Canada thistle in 1950 after two-years' treatment.

Material	Rate per acre (lbs.)	Plant stage		
		Bud	Bloom	Mature
2,4-D	1.2	78	86	157
	2.4	74	84	182
	3.6	61	124	188
2,4,5-T	1.2	180	196	192
	2.4	110	121	197
	3.6	162	143	203

Statistical analysis of the stand data showed a high positive correlation ($r = 0.79$) between the treatment means and the standard deviation. This relationship suggested the need for a suitable transformation of the data to validate the application of analysis of variance.

The logarithmic transformation was used which changed the positive correlation of the means and standard deviations to $r = -0.38$ which was not significant. The log. transformation was subsequently used for the analysis of variance although it tended to overcorrect the mean—standard deviation relationship.

The analysis of variance of the 1950 stand data is shown in Table 2. The thistle stand was reduced to a lower level by 2,4–D than by 2,4,5–T. The bud and bloom stage treatments were more effective than the mature stage. The significant interaction of materials with

time resulted because 2,4–D caused a stand reduction at the bud and bloom stages while 2,4,5–T was less effective and no differences in stand were associated with stage at treatment time.

Table 2. Analysis of variance of 1950 Canada thistle stand data. Log. transformation.

Source	df	Mean Square	F
Reps	7	0.482948	6.76
Materials	1	1.969344	27.56**
Rates	2	0.097622	——
Time	2	1.021252	14.29**
Mat. x Rate	2	0.081996	——
Mat. x Time	2	0.249062	3.49*
Rate x Time	4	0.028868	——
M x R x T	4	0.075250	——
Error	119	0.071442	——
Total	143	——	——

*P <0.05
**P <0.01
C.V. = 13.1

The effects of three years' treatment are summarized in Table 3. The original data were analysed statistically after being transformed to logarithms to remove the correlation between the treatment means and the standard deviations. The difference in the effectiveness of 2,4–D and 2,4,5–T was highly significant in favor of 2,4–D. The treatments at bud and bloom stages were significantly more effective than those at maturity. The coefficient of variation for the 1951 stand data was 20.5 percent.

The thistle stand in 1951 was distinctly reduced as compared with 1950, but there were sufficient thistle shoots in most of the plots to facilitate rapid recovery. The treatments were repeated, and the test was continued into the fourth year.

The emergence of the thistle shoots was slow in the spring of 1952. The weakened condition resulting from four years' treatment was probably a principal contributing factor. Stand determinations by the line-transect method were delayed until June 18, 1952. The summary of the transect stand data is given in Table 4. Many plots in the area and especially within certain effective treatments showed no presence of thistles by the line-transect method. It was apparent that all of the treatments had reduced the stand. The 2,4–D treatments continued to appear better than the 2,4,5–T, and the bud and bloom stage treated plots showed fewer thistle shoots than those treated at maturity.

Table 3. Stand of Canada thistle in 1951 after 3-years' treatment.

Material	Rate per acre (lbs.)	Plant stage		
		Bud	Bloom	Mature
2,4-D	1.2	31	40	108
	2.4	39	74	143
	3.6	27	44	74
2,4,5-T	1.2	120	81	131
	2.4	83	59	105
	3.6	76	77	134

Table 4. Stand of Canada thistle in 1952 after 4-years' treatment.

Material	Rate per acre (lbs.)	Plant stage		
		Bud	Bloom	Mature
2,4-D	1.2	6	12	13
	2.4	3	8	19
	3.6	4	6	13
2,4,5-T	1.2	36	12	26
	2.4	8	5	20
	3.6	5	7	16

It was surprising to note, however, that the stand reduction from 1951 to 1952 was greater for 2,4,5–T than 2,4–D. Furthermore, the stand reduction on the plots treated at the mature stage was greater than that on the plots treated at bud or bloom. These reductions in stand indicate that although the early effects of 2,4,5–T and treatments of either material at maturity stage were relatively small, the thistles eventually died as a result of repeated application. It was concluded, however, that 2,4–D applied at bud or bloom was the best treatment. Bud stage treatment was considered advantageous over bloom stage because it completely prevented seed formation, while some bloom stage treated plants produced a small quantity of seed.

A second criterion of stand evaluation was used in 1952 because of the sparse stand on many plots resulting in several zero-stand plots by the line-transect method. On July 8, 1952 counts were made of all shoots within each plot. The mean number of thistle shoots for each treatment is given in Table 5.

Table 5. Number of Canada thistle shoots per plot in 1952.

Material	Rate per acre (lbs.)	Plant stage		
		Bud	Bloom	Mature
2,4-D	1.2	22	27	53
	2.4	14	29	59
	3.6	10	18	57
2,4,5-T	1.2	81	40	75
	2.4	35	17	65
	3.6	37	27	43

The three rates of 2,4–D at the bud stage of application showed the lowest stand by both the shoot count and line-transect criteria. The treatment of 3.6 pounds of 2,4–D at bud stage resulted in three plots of the eight having no shoots, but one plot of the eight showed 34 shoots. The treatment of 2.4 pounds of 2,4–D at the bud stage showed one plot with no shoots, two with one each, while the one with the most shoots had 39. The 1.2 pound treatment at bud stage showed one zero plot, one plot with one shoot, and others ranging up to a high of one with 74 shoots.

The 2,4,5–T treatment which showed the lowest shoot count was 2.4 pounds applied at the bloom stage. Among the plots receiving this treatment was one with no shoots. The others ranged upward,

with two showing 46 shoots. The variability among the 2,4,5–T treated plots was greater than that among the 2,4–D treated plots. Considerable variability occurred among the replicate plots of each treatment. There was a suggestion from this situation that small areas of somewhat resistant plants occurred randomly throughout the test area. The result of this was that good kills as well as poor kills occurred among the plots of each treatment. The most effective treatments, however, such as 2,4–D at the bud stage gave the greatest frequency of effective control.

Throughout the experiment there was no indication of a significant effect being associated with the rate of application. While the 1.2 pound rate did not show so low a stand of thistle as the higher rates, the differences were small and inconsistent. For an overall summary, the rates were averaged for each material at each time and the results are shown in Figure 1.

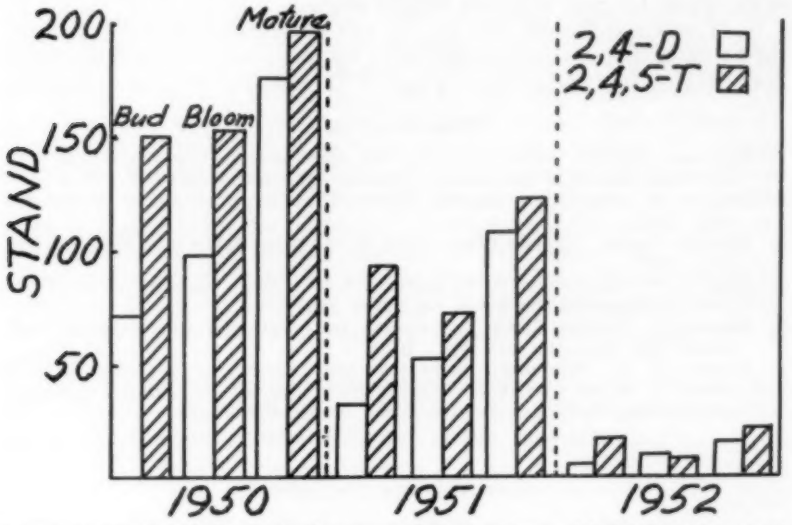

Figure 1. Canada thistle stand after successive treatments with 2,4–D and 2,4,5–T at bud, bloom and mature stages of growth.

It is apparent from Figure 1 that after four years of treatments the stand was reduced to a low level by both materials and at all stages of application. The reduction in stand due to either material over the three years was distinct. The 2,4–D caused an earlier stand reduction than 2,4,5–T. The decrease in stand caused by 2,4,5–T for the first two years, as reflected by the 1950 data, was negligible. However, a rapid decrease in stand occurred from 1950 to 1952. This continued stand reduction after three and four years' treatment suggests the absence of any resistance build-up within the plants. While it was pointed out that considerable variability was evident, it was equally apparent that the plants continued to be killed by repeated application of the growth regulator herbicides.

SUMMARY

1. Canada thistle was treated with spray applications of 2,4–D and 2,4,5–T each at rates of 1.2, 2.4, and 3.6 pounds per acre at the bud, bloom, and mature stages of growth. The treatments were applied once each year in 1948, 1949, 1950, and 1951.

2. Stand density was measured by a line-transect method in which the number of inches of line contacting thistle plants was recorded.

3. No detectable stand reduction was found in 1949 after one year's treatment.

4. The stand as measured in 1950 and in 1951 showed marked reductions in plots treated with 2,4–D at each rate and at bud and bloom stages. The 2,4,5–T treatments were much less effective.

5. The stands in 1952 showed marked reduction with all treatments. However, the greatest frequency of plots with no thistles present occurred among treatments with 2,4–D at the two higher rates applied at the bud and bloom stages.

6. It was concluded that 2,4–D was more efficient than 2,4,5–T for Canada thistle control; and that applications at bud stage were best because of faster, more complete "knock down" of top growth.

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Translocation of Herbicides in Marabu
II. Translocation of 2,4–Dichlorophenoxyacetic Acid Following Foliage Application[1]

J. R. Hay[2]

Foliage applications of 2,4–dichlorophenoxyacetic acid (2,4–D) to marabú *(Dichrostachys nutans)*, a woody weed found in Cuba (3), generally give complete defoliation with varying amounts of stem kill. The older, more basal areas are not killed and the roots are rarely damaged by single applications of 2,4–D. Presumably therefore, little if any of the herbicide moves downward after these applications.

Previously Young and Fisher (12) treated the distal foliage of branches of mesquite *(Prosopis juliflora)* with various formulations of 2,4–D and 2,4,5–T while the more proximal parts were shielded with cardboard. A maximum of 10 inches of stem was killed below the treated area, and this only in a single instance; the average was much less. Blair and Fuller (1) made foliage applications to the top 6 inches of mesquite seedlings with 2,4–dichloro–5–iodo^{131}phenoxyacetic acid (2,4–D–I^{131}). Less than 3% of the applied I^{131} moved below the treated area, and this presumably sets a maximum value on the movement, since some of the I^{131} detected may have already been liberated from the molecule. In any event, the result certainly indicates that strictly limited amounts of the chemical moved down. In general it has been found that for best results with foliage applications to brush (9), it is necessary to obtain thorough coverage of the lower parts; this too suggests that downward movement is negligible.

The present work reports on measurements made of the amount of 2,4–D that was translocated following its application to the foliage of marabú and on the pathways of this movement.

Materials and Methods

The same general method was used in this as in the earlier work (3, 6) wherein the applied auxin was extracted from various parts of the treated plants at different intervals of time after application. The amounts recovered were again assayed with the slit-pea test. Since field trials had shown that 2,4–D was equally as effective as 2,4,5–T in controlling marabú, and since 2,4–D is somewhat more active in the pea test, 2,4–D was used in these trials rather than 2,4,5–T. It was applied as the butoxyethanol ester of 2,4–D.

For these experiments uniform suckers, or ratoons, 1 or 2 feet high were used. Aqueous solutions were applied to all the leaves on the outer 15 to 30 cm of the ratoon while the bottom section of the

[1]Contribution from the Biological Laboratories, Harvard University, Cambridge 38, Mass.

[2]Agronomist, Field Husbandry Division, Central Experimental Farm, Ottawa, Canada.

stem was protected with sheets of polyethylene plastic. After treatment the sheets were removed and the lowest point of treatment marked with a tag. In each test, 7 cm sections were taken from two plants below the treated area at various times and the amount of auxin therein determined in the usual way. No auxin activity was detected in samples from untreated stems. As shown earlier (6), the test is about ten times more sensitive to 2,4–D than to the natural auxins of growing shoots. Hence, any activity detected in the samples from treated plants could be attributed entirely to the added synthetic auxin which had moved down the stem.

Negative results, which were obtained in preliminary extractions made at more than one day after treatment at first suggested that there was no downward movement whatever (5). However, in extractions made at short intervals after application it was discovered that small but measurable amounts of 2,4–D did move downward in the stems. The results of a number of these trials are reported in Table 1. The 2,4–D was detectable at 8 to 15 cm and 12 to 19 cm as well as just below the treated area. This indicated that the movement was rapid, even though the amounts recovered were very small.

Table 1. Recovery of 2,4–D from 7 cm sections of stems below the treated area when approximately 4 or 10 mg were applied to the foliage of young ratoons. (Ten mg per plant equals approx. 2 lb/acre.)

Amount applied (mg)	Dist. below treated area (cm)	No. of samples	Hours after application	Ave. recovery µg/sample
0	1–8	3	—	0.0
4	1–8	3	6	1.7
4	8–15	2	6	1.5
4	12–19	1	6	1.0
4	1–8	3	24	0.0
4	1–8	2	30	0.0
10	1–8	5	6	2.7
10	1–8	10	24	2.0
10	1–8	4	30	0.0

Samples taken from just below the treated area at 6 hours after receiving 4 mg of 2,4–D per plant yielded an average of 1.7 micrograms while those receiving 10 mg per plant gave an average of 2.7 micrograms. Every test for 2,4–D made at 6 hours gave positive results, but at 24 hours none was recovered from plants treated at the low rate and only 5 out of 10 trials gave positive tests for auxin when the higher amount was applied. A negative test for auxin was always obtained at 30 hours after application.

All these treatments were made at about 10 am so that 6 hour samples were taken at 4 pm on day 1 and the 24 hour samples were taken at 10 am on day 2. A wave of downward movement took place on the first day as was indicated by the amount recovered at 6 hours, but a similar wave on the second day did not occur since the 30 hour samples, taken at 4 pm on day 2, yielded no auxin. It is clear that under these conditions movement downwards ceased at about 24 to 30 hours and that the material which did move down was degraded rather quickly. This conclusion was confirmed by making a

second application of about 4 mg of 2,4–D per plant at 24 hours after the first application, and then extracting 6 hours later or 30 hours after the initial treatment. No auxin was found in the test samples, so that presumably none of the second application was translocated.

The fact that lesser amounts of 2,4–D were recovered at 30 hours than at 6 hours indicates not only that translocation soon ceases but also that the material is being broken down in the stems within this time. Degradation in bean seedlings has also been reported (6).

Indirect evidence as to movement from leaves. During the course of the above experiments with foliage applications it was noted that bud development on 2,4–D treated ratoons was delayed for many weeks. When young untreated ratoons were cut off, on the other hand, new shoots normally developed on the stumps within ten days or less, either from axillary buds or from adventitious buds formed at the cut-surface. It follows that although the amount of 2,4–D translocated downward is small, it is large enough to bring about the typical bud inhibition. The speed of this translocation was estimated by spraying a number of selected ratoons and then cutting them off close to the base either 1 or 4 days afterwards. The results, in Table 2 show a definite inhibition in the development of buds on the stumps. 2,4–D is translocated downwards in inhibitory, but not in toxic concentrations, within 1 day. A further 3 days causes only a slight increase. Similar observations were also made on the stumps of some ratoons cut at 6 hours after treatment, the bases of which had been protected with plastic shields at the time of treatment. Since the buds on these stumps also showed some inhibition of regrowth, the inhibitory amounts of 2,4–D must have moved down even within 6 hours.

Table 2. Per cent of stumps showing regrowth at various dates when the tops were removed with and without previous treatment of approx. 10 mg of 2,4–D per plant to the foliage on Nov. 20, 1953. Tops were removed at one and four days after spraying.

Date	Tops removed at 1 day		Tops removed at 4 days	
	No 2,4-D	Plus 2,4-D	No 2,4-D	Plus 2,4-D
Dec. 8/53	100[1]	0[2]	100[1]	0[2]
Dec. 22/53	100	0	100	0
Jan. 8/54	100	7	100	0
Feb. 1/54	100	33	100	7
Feb. 27/54	100	40	100	40
Apr. 7/54	100	60	100	87

[1]—10 plants
[2]—15 plants

It is clear from these experiments that the amounts detected by extraction in the protected lower parts (Table 1) correspond to those which cause physiological inhibition of bud development. It is of interest that the leaves on new shoots arising from the stumps after foliage treatments showed typical 2,4–D abnormalities.

When young ratoons, such as those used here, were treated with

about 10 mg of 2,4–D they were usually killed to the ground line within 4 to 5 weeks. When their bases were shielded, however, there was a sharp difference between the treated and the untreated parts, the latter remaining alive for considerably longer periods of time and generally indefinitely. Of 28 bottom-shielded ratoons which were observed for 4 to 5 months, 9 were eventually killed to the ground while the protected parts of the others remained alive. Thus, the small amount which moved below the treated area was not only great enough for inhibition, but was probably near the threshold level for toxicity to these young ratoons.

Because 2,4–D is degraded in the plant and because it was not known how the 2,4–D was distributed in the highly variable underground parts of the marabú plants, it is difficult to determine exactly what fraction of the applied material was actually transported. However, an estimate can be made by determining how much moved through a section of the stem during the 24 hour period of translocation.

It was known that 6 hours after 10 mg of 2,4–D were applied to the upper 12 inches of a basal shoot approximately 2 μg could be extracted from a 7 cm section of the shielded stem lower down (see Table 1). Now, if it is assumed that transport proceeded at 2 cm per hour (Went and White (11) calculated 0.9 mm per hour for indoleacetic acid in the Avena coleoptile) then a molecule of 2,4–D would take 3.5 hours to pass through the 7 cm section. In other words, if all the auxin in the section was in transit, the content at any instant would be that which would pass through in 3.5 hours. Thus, if 2 μg moved through in 3.5 hours, a total of $(24/3.5 \times 2)$ or about 14 μg could have moved through this section in 24 hours. Since 10,000 μg of 2,4–D were applied to the treated area (about 72 square inches of leaf surface) it follows that only 0.14 per cent of this was transported downward. (If the actual rate was 10 times the assumed rate, the fraction moved would still only be 1.4 per cent.) It thus appears that only very small quantities of the applied auxin moved from the leaves. More effective herbicidal action could be expected if some of the excess 2,4–D over that needed for leaf kill could be induced to move out rather than remain in the leaves. This would be especially true if, as was calculated above, the amounts that do move are close to the threshold for toxicity.

The following experiments were made in order to discover in which tissues the downward movement from foliage treatments took place. Plastic shields were placed over the base of ratoons from which one inch rings of bark had been removed. The shield covered the ring and about 1 cm of the stem above it. Six hours after application of the 2,4–D to the foliage, 7 cm sections from two ratoons were taken from just below the ring for extraction. No 2,4–D was recovered in two such trials. The data of Table 1 show that approximately 3 μg would be expected in similar samples taken from intact shoots. This indicates that the 2,4–D moves down in the bark, or in the cambium, or in the young derivatives of the cambium. To test this further, a downward-pointing flap of bark 5 cm long and in-

volving about half the circumference of the stem was cut away. The flap was about 7 cm below treated area. Figure 1 is a diagram of such a flap, and also shows the samples taken for extraction with the amounts recovered from each. Each sample consisted of sections taken from 4 ratoons and each figure is the average of two trials. The leaves were sprayed in the usual way, using 10 mg of 2,4–D per shoot. Negative tests were invariably obtained when flaps from four untreated plants were extracted.

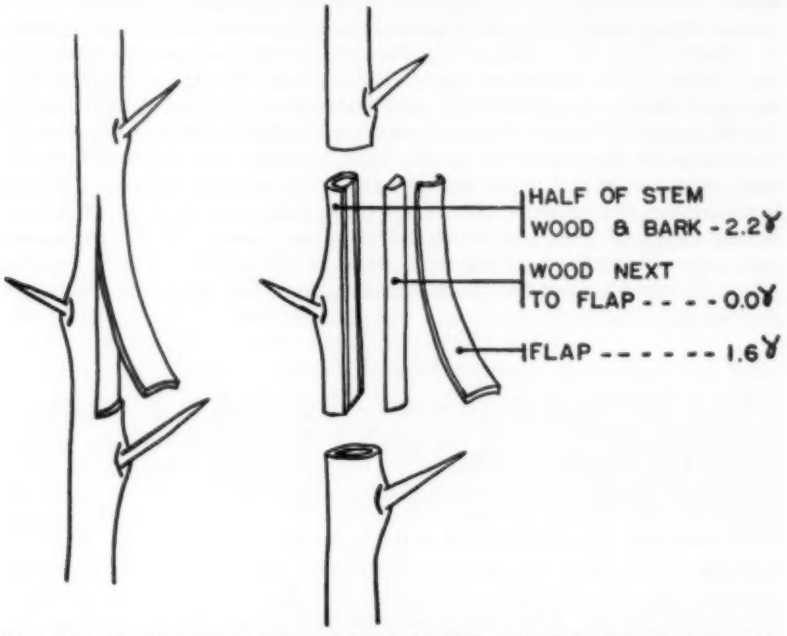

Figure 1. Left, diagram of downward pointing flap of bark on marabú stem, and, right, the various samples taken for extraction with the amounts of 2,4–D recovered from each. (See text)

From the intact half of the stem away from the flap, 2.2 μg of 2,4–D were recovered. On the flap side of the stem none was recovered from the wood and 1.6 μg from the flap of bark. This confirms that the 2,4–D moved in tissue outside the wood but does not distinguish between cortex, phloem or cambium. In a second flap experiment, therefore, the inner surface of the flap was scraped with a sharp knife to destroy the cells of the cambium region. Extraction of the remaining flap tissue then yielded 2.1 μg so that a large part of the auxin movement evidently occurred in the mature bark.

These results support the early findings of Cooper (2) who concluded that auxins moved down in the phloem of woody plants. They do not agree with the conclusions of Söding (10) who concluded that the cambium and its daughter cells are the principal path of transport of auxin. Furthermore, there was no evidence in

our trials for downward transport in the wood as Oserkowsky (8) found in dormant stem sections of pear. The data show that at least part of the auxin moving down in the stem from the leaves goes by way of the mature bark. The possibility of additional auxin moving through the cells of the cambium region, of course, is not eliminated in flap experiments.

Upward movement from foliage applications. To study upward movement from foliage treatments, the tops of ratoons were protected with plastic shields and the plants subsequently sprayed with about 10 mg of 2,4–D each. Plants treated in this way showed epinastic effects at the tips, indicating that the auxin had moved from the leaf to the stem, and been carried upward to the tips. This test was repeated using the relatively non-volatile diethanolamine salt of 2,4–D so that the curvatures at the tips could not have been caused by vapors of the ester of 2,4–D. Furthermore, this upward movement was confirmed when a bioassay of extracts of the top 3 leaves from within one of these protected tips yielded about 4 μg of 2,4–D. When a ring of bark was removed from the bottom of the protected area, epinastic effects at the tips were of about the same intensity. Thus, upward movement from treated leaves can take place through the wood.

DISCUSSION

There was a limited downward translocation of 2,4–D after it was applied to the foliage, especially as shown by the "flap" experiments. The amount moving down may have approached the toxic level, and, in any event, it was large enough to inhibit the development of new shoots for some months even when the treated tops were removed. It is possible that under other conditions the amounts moving down may be greater than that noted here. This would account for the sporadic reports of excellent kills of deep-rooted plants by 2,4–D. The visible abnormalities in the leaves of the shoots, when they eventually developed, further indicate the presence of the auxin in moderate amounts. The translocation evidently takes place in the bark but some of the 2,4–D may subsequently move upward again through the wood.

Downward translocation in the stem apparently ceased at 24 hours although analysis showed that large amounts of 2,4–D were still present in the leaves. Also, none of a second application of 2,4–D, which was made 24 hours after the first, moved down the stem. These data strongly suggest that the mechanism responsible for translocating 2,4–D from the leaves and in the stem is disrupted by the applied auxin itself. The same conclusion was drawn from other experiments on the translocation of 2,4–D (4, 7) and for 2,4,5–T in marabú (3).

When auxins are applied as herbicides, unphysiologically high concentrations of the auxin are expected to move through cells which may themselves be adversely affected. When recommendations for the control of woody plants are made it must be recognized that

toxic quantities of 2,4–D or 2,4,5–T probably do not move through living tissues of the stem.

Single foliage applications do not kill many marabú plants but, on the other hand, there is some downward transport of 2,4–D and efficient machines are available for economical application, so that large areas can be efficiently treated within short periods of time. If a chemical method for woody plant control is to be effective on a large scale it must involve some method such as this. However, it is clear that, at present, single applications do not give marked stand reductions of this species so that planned programs of successive retreatments are essential.

One foliage application of 2,4–D to marabú usually gives complete defoliation, at least partial stem kill and some 3 months delay in regrowth. Thus foliage applications with periodic retreatments have been used to "control" this species with considerable success. By preventing excessive ratoon development, it has been found that the grass is relieved from competition with the marabú and the grazing cattle are not hindered by the thorny top growth of the species. The cost of these applications can be profitably returned through the value of the forage made available to the cattle. Furthermore, the effects of retreatments in Cuba have been additive so that eventually marked stand reductions result.

On sparsely infested areas, it may be more economical to treat individual plants by the basal-bark method of application which gives greater immediate root-kill. However, the cost of this method goes up in proportion to the density of the stand and the point is reached where it becomes more economical to make repeat foliage applications where the cost is more or less independent of the density.

SUMMARY

Direct measurements were made of the amount of 2,4–D that was transported in a woody plant after it had been applied to the foliage. A highly sensitive bioassay which had been first worked out in the laboratory with seedlings was used. Less than 1 per cent of the applied 2,4–D was found to move down from foliage applications. This limited movement ceased at about 24 hours so that most of the herbicide was trapped in the leaves. The small amount that did move down went through the bark and not the wood. Some of the 2,4–D was degraded by the marabú plants. Phytotoxic amounts did not move through living tissues and it was suggested that this is due to the detrimental effect which such concentrations might have on the transport mechanism. The significance of these results to the practical control of marabú is discussed.

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The Weed Control Demonstration Program in Michigan

S. K. Ries[1]

Most farmers are not taking full advantage of the information available on herbicides and weed control methods. With few exceptions there is too long a delay between the development of a new weed control practice and its use on the average farm. This lag may be attributed to the following factors:

1. Failure of public and commercial extension workers to inform individual farmers.
2. Unsatisfactory experiences by farmers due to improper use of herbicides.
3. Grower unwillingness to try something new without visual proof.
4. General complexity of herbicide usage.
5. Unwillingness of a large number of farmers to be the first to accept a new practice.

Michigan State University extension specialists and research workers attempted in 1955 to determine the effectiveness of a concentrated effort to encourage demonstration plots in several counties.

Methods

In 1954, four agricultural agents were furnished small plot sprayers, chemicals, plot stakes, and information. These agents applied selected herbicides recommended for use on vegetable crops. At the end of the season, the agents concluded that they and the farmers in their counties had not only learned about new practices, but had also learned much about the factors responsible for the success or failure of an herbicide. They learned the importance of weather conditions prior to application and the importance of stage of weed and crop growth at time of application. The sprayer supplied was unsatisfactory because of its complexity and the remote possibility of personal injury. Besides the four participating agents, several other agricultural agents expressed a desire to participate in the program in 1955, and inquired about expanding the program to other crops.

The extension administration, along with specialists in subject matter departments, decided that this program should be expanded in 1955 to include not only vegetables, but the whole field of weed control, with the program available to any Michigan agricultural agent. An Extension Weed Control Committee was formed with representatives from the departments of Agricultural Engineering,

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Botany, Farm Crops, and Horticulture.[2] The following program was proposed by this committee and offered to each agricultural agent in the state. The program was voluntary and the responsibilities were divided as follows:

Responsibilities of the committee

1. Furnish agricultural agents with chemicals, signs, plot stakes and to suggest equipment for use in the demonstrations.
2. Assemble and disseminate to agents useful and timely information concerning weed control practices.
3. Provide the best available information regarding methods of laying out and conducting weed control demonstrations.
4. In so far as possible, assist in conducting weed control tours and in interpreting results of the demonstrations, when requested by the agricultural agent.

Responsibilities of the agricultural agents

1. Purchase and use the sprayer designed and recommended by the committee.
2. Limit demonstrations to not more than ten different crops or weeds.
3. List the crops and weeds selected for demonstrations and return this list by March 28.
4. Properly label, by means of signs, the weed control demonstration areas.

A knapsack sprayer was designed in cooperation with a manufacturer to meet the following specifications, which the committee felt were necessary to accurately apply chemicals to demonstration areas:

1. 3-gallon stainless steel tank and pump.
2. Built-in pressure regulator to deliver the spray at a pressure of 25 lbs. per square inch.
3. A 3-nozzle brass boom to accurately spray a 4-foot swath, and easily changed to one nozzle.
4. A chain to indicate the correct spraying height.
5. Six brass Tee-Jet tips (80015 and 8003) to provide a range of 20 to 40 gallons per acre. The tips were not used in Tee-Jet nozzle heads, but in heads modified to use Tee-Jet tips.
6. 50 mesh screens in the boom and at each nozzle.
7. Cost of sprayer $34.80 complete.

After enrolling in the program and listing the crops to be worked with, each agent was shipped the following materials:

1. Chemicals—each agent was given the chemicals necessary to work on the crops selected. The chemicals were distributed in

[2]Members of the Extension Committee were as follows: R. F. Carlson, Department of Horticulture; B. R. Churchill, Department of Farm Crops; B. H. Grigsby, Department of Botany and Plant Pathology; L. V. Nelson, Department of Farm Crops; R. G. White, Department of Agricultural Engineering; and S. K. Ries, Department of Horticulture, Chairman.

the manufacturer's container when possible or put up in gallon cans or ice cream containers with duplicate manufacturer's labels.

2. 20 to 40, 18-inch white stakes.
3. 1 to 3 metal signs 2 feet wide and 3 feet long, and 2 six-foot stakes to support each sign. The signs read as follows: "Demonstration, Michigan State University, Cooperative Extension Service."
4. A set of measuring spoons, a measuring cup and wax pencils.
5. A manual which contained the following:
   a. Directions for setting up weed control demonstration plots including calibration of the sprayer, plot lay-out and designation.
   b. A dilution table designed to give the teaspoons of stock herbicide necessary to cover an area 800 square feet at a rate of one pound per acre.
   c. Suggested practices for crops, brush, specific weeds, lawns, and soil sterilization.
   d. Catalogs on several commercial weed control sprayers, pumps and nozzles.

During May and June, several letters, entitled "Timely Hints," were written to each participating agent to provide information on the best time to conduct particular demonstrations, and on methods of evaluating them. Members of the committee also visited various agents and helped them with their problems.

In October, each agent was asked to help evaluate and improve the program by answering questions, offering suggestions for the 1956 program, and listing the demonstrations he conducted, including the crops sprayed, chemicals used, and the results of each demonstration.

RESULTS AND DISCUSSION

Forty-four agricultural agents representing 46 counties enrolled in the extension weed control program. The agents were fairly well distributed throughout the state. Forty-three of these agents filled out and returned the questionnaire. Seven agents, for various reasons, put out no demonstrations. The remaining 36 agents conducted 618 demonstrations—an average of about 17 demonstrations per agent. There was a wide range of activity among the agents participating in the project.

The information in Table 1 indicates that all the agents who answered the questionnaire wanted to continue the program in 1956. In general the handbook was satsifactory; however, the following suggestions were made for improving the handbook:

1. Supply more specific information on weeds, such as, botanical description, most effective herbicides on specified weeds, and details as to time and rate of applications.
2. Supply a list of the herbicides, their technical name, common trade names and approximate costs.

Table 1. Answers to questions given agents participating in the extension weed control program.

Question	Answer	
	Yes	No
1. Would you like to continue the project next year?	43	0
2. Was the handbook satisfactory?	38	1
3. Would youl ike to have more "timely hints" if the program is continued?	40	0
4. Do you want more personal assistance from specialists with your weed control program?	22	13
5. Were you satisfied with the sprayer?	31	9
6. Would you be willing to apply small amounts of experimental materials such as the amino triazole on poison ivy?	37	2
7. Were you satisfied with the chemicals, stakes, signs, and materials furnished?	34	2
8. Would you like a meeting concerning the conducting of weed control demonstrations?	30	6
9. If you could have such a meeting; where should it be held?		
At University	8	
District conference	13	
Locally	5	

The "timely hints" was of value and should be continued.

Opinions were divided on the desire for more personal assistance from specialists. Additional assistance was requested by 22 agents while 13 felt that the information supplied was sufficient. This seemed to indicate that assistance by specialists in the field should continue to be provided when requested by the agent.

Only nine agents expressed dis-satisfaction with the sprayer, though several encountered some trouble. The committee and manufacturer devoted considerable effort to the problem of providing a good sprayer for the agents. Unfortunately, the sprayers were not in the agents' hands until the first week of May. This delay, plus the troubles encountered, undoubtedly decreased the effectiveness of the program. Following is a list of the troubles encountered and possible corrective measures.

1. The pressure regulator on several sprayers would not pass wettable powders. The diaphragm ruptured in several regulators, and the regulator was too complex for the average agent to take apart, clean and re-adjust. If a better regulator cannot be found, the regulator should be eliminated.
2. Tee-Jet nozzle heads should replace the wide-mouthed type provided so that standard 50-mesh screens may be used.
3. The brass boom was too easily bent or broken and should be replaced by a boom made out of 1/8-inch galvanized pipe.

The chemicals, stakes, and signs provided were in general satisfactory. However, the signs and six foot stakes were too bulky to mail. Supplying 44 agents with eight to ten herbicides in quantities of one-half to one gallon for the liquids and one-half to two pounds for the powders was a considerable task. This problem could be reduced if the agents would obtain the chemicals from local dealers

where possible. This should work to the advantage of both the agent and the dealer, since the dealer would become better informed concerning the chemicals which growers would most likely request.

Thirty of the 36 agents answering thought a meeting should be held concerning the application of the demonstrations. The majority opinion was that this meeting should be held at district conferences. Since the agents, themselves, have requested a weed control demonstration meeting, it seems advisable to hold a series of district meetings to train the agents on the following:

1. Principles of weed control.
2. Laying out demonstrations.
3. How to calibrate, operate, and maintain both small plot and commercial sprayers.
4. Evaluation of results of herbicide applications.
5. Use of information derived from the demonstration.

A second portion of the questionnaire was concerned with the crops, weeds sprayed, the chemicals used and with the results. This information was of interest to the committee and other agents but is too lengthy for inclusion here.

Summary

An extension weed control program was introduced in Michigan with the ultimate objective of gaining a wider usage by farmers of existing weed control practices. The program was conducted under the leadership of Michigan State University extension specialists and research personnel cooperating with agricultural agents.

Forty-four agents enrolled in the program. Thirty-six of these agents had active programs, applying 618 demonstrations to 36 different weed control problems.

The agents made many suggestions that should make a better program in 1956, and all of them would like to continue the project in 1956. In addition, it seems advisable to make the program available again to other Michigan agents.

The program, in general, was well accepted by the agricultural agents for the following reasons:

1. Weed control is of interest to *all* farmers.
2. Chemical weed control is still relatively new and undeveloped. This program afforded means by which the agents could become better acquainted with chemical weed control through "learning by doing."
3. Many of the weed control demonstrations were useful for news stories, radio discussions, and twilight meetings.
4. Results from chemical weed control may be observed throughout the season, rather than at specific times, such as at crop harvests.

The extension specialists thought that the program was advantageous because it appeared to hasten the adoption of proved weed control practices by farmers and stimulated the interest and par-

ticipation of county agricultural agents. Sixty-one agricultural agents enrolled in the 1956 program.

It is not possible at this point to conclusively estimate the effectiveness of this program in gaining a wider usage of good weed control practices by farmers. But any evaluation may be reasonably based on the assumption that any teaching method or procedure which results in a better informed agricultural agent will also result in better informed farmers. Besides obtaining better informed agricultural agents, the demonstrations themselves have undoubtedly shown the farmers on whose farms they were conducted the effectiveness of the practice. In many cases communication between farmers probably has resulted in wider use of newer herbicidal practices.

The Michigan Extension Weed Control Program can be improved in the future by emphasizing and encouraging effective individual demonstration projects. It would also be advisable to attempt to evaluate the effectiveness of this type of program in the increased adoption by the farmer of the practices demonstrated.

The Effect of Aqueous Extracts of Plant Tissue on Germination of Seeds and Growth of Seedlings[1]

DUANE LE TOURNEAU, G. D. FAILES and H. G. HEGGENESS[2]

EXTRACTS of many plants have been shown to contain germination and growth inhibitors (1, 2, 3, 4, 5). In some instances these inhibitors play a role in the distribution of species. Thus dried *Encelia* leaves contain a material which leaches slowly into the ground and inhibits the growth of species susceptible to it (2). This suggests that certain weeds may be aided in their competition with crop plants by similar inhibitors. Helgeson and Konzak (4), for example, found that aqueous extracts of field bindweed *(Convolvulus arvensis)* and Canada thistle *(Cirsium arvense)* inhibited the germination of seeds and growth of seedlings of certain crop species.

Aside from their role in species interaction, these inhibitors are of interest for other reasons. In only a few instances have these inhibitors been isolated or their mode of action determined. In many cases these inhibitors do not appear to be similar to known plant products. It is possible that these materials or their analogues might find application if their constitution were known. In addition, bioassays involving germination and root growth inhibition may be used to determine the quantity of herbicide present in or on plants. In using such assays it is necessary to know if non-treated tissue contains materials active in the assay and if they might interact with the herbicide to be assayed.

The following work was undertaken in order to obtain information on the possible occurrence of germination and growth inhibitors in common weed and crop species.

MATERIALS AND METHODS

Plant material was largely from field collection but several of the species, particularly crop plants, were grown in the greenhouse. In all cases where plants were harvested in the field, collections were made in areas where, so far as was known, there had been no previous treatments with herbicides, fungicides, or insecticides. Plants were cut at the ground line and placed in a forced air drier at 55 to 60° C for 24–48 hours. After drying, the plants were ground to pass a 40 mesh sieve in a Wiley mill and stored in screw cap bottles.

Extracts were made by weighing out a quantity of plant material (1–5 gms) and adding to it 100 ml of distilled water. Concentrations are expressed as 1/100, 2/100, etc., indicating the amount of material extracted with 100 ml of water. The mixture was immediately autoclaved for 15 minutes at 20 lbs pressure. The suspension was filtered while hot on a Buchner funnel and the liquid sterilized by autoclaving in cotton stoppered flasks. Ten milliliter aliquots were

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Table 1. The effect of aqueous extracts of plants on germination and growth of Mida wheat. Germination period 4 days.

Family	Species	Concentration[1]	Percentage germination	Range of coleoptile length (cm)	Range of root length (cm)
Control	——	–	91	3–5	4–6
Asclepidaceae	*Asclepias syriaca*	2	64	2–4	1–2
		5	51	1–3	<1
Carophyllaceae	*Lychnis alba*	2	71	2–4	2–3
		5	45	1–2	<1
Chenopodiaceae	*Chenopodium album*	2	69	2–3	1–2
Compositae	*Ambrosia trifida*	2	68	1–3	1–2
		5	40	0.5–1.5	<1
	Cirsium discolor	2	66	2–4	1–2
		5	47	1–2	<1
	Iva xanthifolia	2	64	1–2	1–2
		5	50	0.5–1.5	<1
	Solidago spp.	2	55	1–3	2–3
Cucurbitaceae	*Cucurbita maxima*	2	75	2–3	0.5–1
Euphorbiaceae	*Euphorbia esula*				
	stems	5	72	1–2	1–2
	leaves	1	73	2–4	1–3
		2	69	1–3	1–2
		3	61	1–3	0.5–1.5
		4	53	1–2	<1
		5	56	<1	<1
Gramineae	*Avena sativum* var. Clinton	2	81	2–4	1–2
	Triticum vulgare var. Mida	2	73	2–3	1–3
	Zea mays var. Minhybrid 504	2	71	2–3	1–2
		5	69	1–2	<1
Labiatae	*Nepeta cataria*	2	58	2–3	1–2
		5	40	1–2	<1
Leguminosae	*Pisum sativum* var. Alaska	2	71	2–3	1–2
		5	55	0.5–1.5	<1
	Soja max var. Ottawa-mandarin	5	60	0.5–1.5	<1
	Phaseolus vulgaris var. Black Wax				
	leaves	5	60	0.5–1.5	<1
	stems	5	87	2–3	1–2
	entire plant	5	71	1–2	0.5–1.5
Liliaceae	*Polygonatum* spp. (leaves only)	2	65	2–4	1–3
		5	57	1–3	1–2
Malvaceae	*Hibiscus trionum*	2	71	2–4	2–4
	Malva spp.	2	69	2–3	1–2
Plantaginaceae	*Plantago* spp.	2	83	2–4	1–2
Polygonaceae	*Polygonum pennsylvanicum*	2	76	2–3	1–2
Portulacaceae	*Portulaca oleracea*	2	75	2–3	<1
Solanaceae	*Lycopersicon esculentum* var. Marglobe	2	58	1–3	0.5–1.5
Umbelliferae	*Petroselenium hortense*	3	68	2–4	1–3

[1]Concentration listed is equal to number of grams of dry plant material extracted with 100 ml of water.

transferred to sterile petri plates containing germination blotter paper. Aliquots were also removed for determination of pH (Beckman glass electrode pH meter) and total solids.

Germination tests were made with Mida wheat that had been surface sterilized 5–7 minutes with 2% sodium hypochlorite and rinsed 3 times with sterile distilled water. Immediately after surface sterilization 45 to 55 seeds were transferred to the petri plates. Three plates were prepared for each extract. Control plates contained sterile distilled water. Germination was carried out in a Mangelsdorf germinator at room temperature (20–25° C). Observations of the plates were made daily and final measurements made after 4 days. Seeds in which the coleoptile or seminal root had attained lengths of 1 mm or more were counted as germinated. In addition, the range of coleoptile and root length of germinated seeds was obtained by measuring 10 to 15 seeds per dish. Certain extracts were also tested against Alaska peas. Ten peas per plate were used with the same procedure as outlined above. Radicle length was measured at the end of 5 days.

RESULTS AND DISCUSSION

The results of the experiments with wheat are summarized in Table 1. One lot of Mida wheat was used to assay all the extracts. Each extract was tested at least at two different dates. Thus the results were obtained from a minimum of 10–15 measurements on each of 6 plates. Figures listed for root and coleoptile length represent the range of length attained by those seeds that did germinate. The effect of an extract on root and coleoptile growth did not vary appreciably when tested at different dates. Germination percentages were more variable. The variation was often as great as 10% when the same extract was tested at different dates. The effect of selected extracts on pea germination and root growth is summarized in Table 2. Figures 1 and 2 illustrate the effect of typical extracts on wheat and peas, respectively.

All materials tested, 23 species representing 16 families, were effective in inhibiting wheat germination, but usually did not inhibit pea germination. All extracts inhibited seedling growth of both wheat and peas. In general, extracts of crop species appeared to be as inhibitory as extracts of weed species. In most cases, in-

Table 2. The effect of aqueous extracts of plants on Alaska peas. Two grams of plant material extracted with 100 ml. water. Germination period—5 days.

Species	Percentage germination	Length of primary root (cm)	Percentage inhibition of root growth	Solids (mgs./10 ml.)
Control	95	4.3	—	—
Pisum sativum var. Alaska	97	2.2	49	39
Lycopersicon esculentum var. Marglobe	100	2.3	47	90
Zea mays var. Minhybrid 504	97	2.3	47	42
Lychnis alba	93	1.7	60	34
Iva xanthifolia	87	2.0	53	37

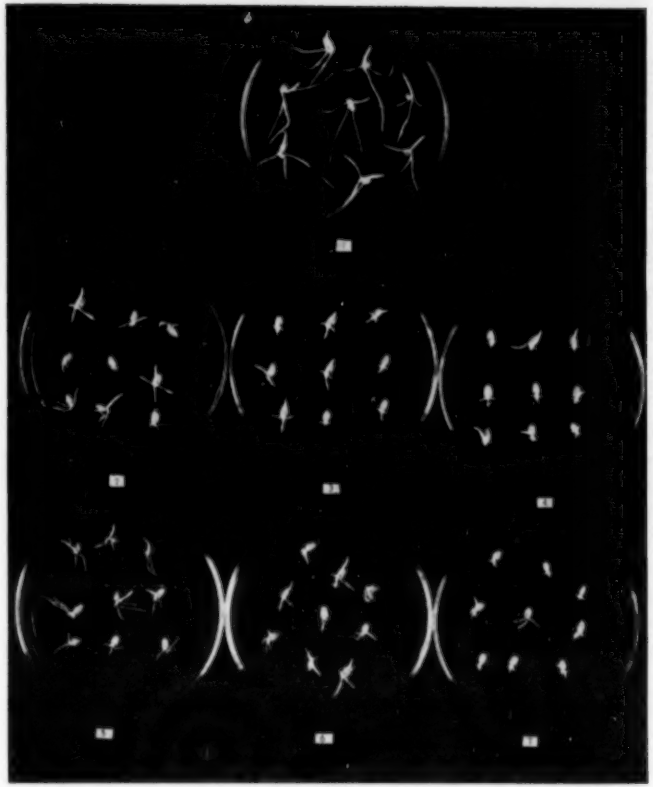

Figure 1. The effect of aqueous extracts (2 gm/100 ml H_2O) of certain species on the growth of germinating wheat. 1. control, 2. peas, 3. corn, 4. tomatoes, 5. *Lychnis alba*, 6. *Euphorbia esula*, 7. *Iva xanthifolia*.

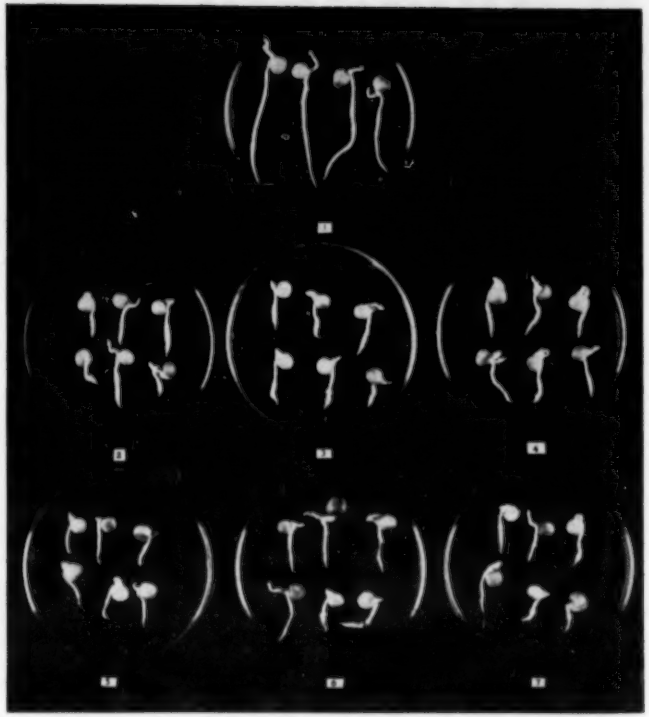

Figure 2. The effect of aqueous extracts (2 gm/100 ml H_2O) on radicle growth of germinating Alaska peas. 1. control, 2. peas, 3. corn, 4. tomatoes, 5. *Lychnis alba*, 6. *Euphorbia esula*, 7. *Iva xanthifolia*.

creasing the amount of material extracted resulted in increased inhibition.

From experiments to date, it does not appear that either pH or osmotic pressure of the extracts is responsible for inhibition. The pH's of the extracts were all in the range 4.9 to 6.8 with the majority from 5.1 to 6.0. Total solids determinations were made on some of the extracts (Table 2). Assuming some average molecular weight of the materials in solution, approximate osmotic pressure values may be calculated. If molecular weights of the order of 50 to 150 grams per mole are used, osmotic pressures of the order of 0.5–2 atmospheres are obtained. The latter figure would probably approach a maximum value. Experiments with buffer and sugar solutions have shown little, if any, inhibition in this range of osmotic pressure. For example, in an experiment with peas, root length attained in 4 days in distilled water was 4.2 cm. Root length in 0.1 M glucose (2.24 atmospheres) was 4.1 cm, while in 0.2 M glucose or 0.1 M salt solutions[3] (4.5 atmospheres) average root lengths were 3.9 and 4.0 cm, respectively. Wheat root growth was somewhat more sensitive than pea root growth, inhibition occurring at approximately 3 atmospheres. Similarly, results of pH tests have shown no inhibition in the range encountered with the present extracts. This is in agreement with results reported by other workers (3).

It thus appears that inhibition is due to materials present in the extracts. All such inhibitors are present after autoclaving and are water soluble. Further studies on the nature of the inhibitor have been made only with leafy spurge (6). With some other plants (tomatoes, peas, *Iva xanthifolia* and *Ambrosia trifida*), it has been determined that the inhibitory fraction remains after ether extraction.

From these results it appears that extracts of some plants are more inhibitory than others. Although this may be true, several facts should be kept in mind. The amount of inhibitor may depend on the stage of maturity when the samples are collected. In preliminary experiments, extracts of young bean and spurge plants were more effective than similar extracts of older plants. Similarly, Konis (5) suggested that leaf sap of young plants was more inhibitory than leaf sap of older plants of the same species. Also, it has been found with spurge (Table 1) that extracts of leaves are more inhibitory than stem extracts. Thus, extracts of species which have a high ratio of leaf to stem material might appear more inhibitory than a species where this ratio is low. In addition, it has been established with several species that one extraction does not completely remove all inhibitory activity. Thus, at present it is difficult to adequately compare the potency of extracts of different species.

The results of this investigation agree with those of a number of other workers reporting germination and/or growth inhibitors in a variety of plants (1, 2, 3, 4, 5). Konis (5) has suggested that the inhibitory materials of leaf sap are more than germination inhibi-

[3]A solution containing KNO_3, KCl, $NaNO_2$ and NaCl, all at 0.025 M.

tors and that they are growth regulating substances within the plant. In this connection it was found in the present study that extracts of wheat and pea plants were inhibitory to the growth of wheat and pea seedlings. This suggests the possibility of materials in the shoot inhibiting or controlling root growth. If it is found that these materials are growth regulators or inhibitors, they or their analogues may well find practical applications. Regardless of the nature or role of these inhibitors, it is necessary to be cognizant of their effects in bioassay procedures using extracted plant tissues.

SUMMARY

Aqueous extracts of dried plant material representing 23 species inhibited wheat germination and growth of germinating wheat and peas. This inhibition appears to be due to materials in the extracts. All such inhibitors were present after autoclaving and are at least partially water soluble.

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Weed Control in Pastures in the North Central Region

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WEED LOSSES

WEEDS in pastures are eaten in varying amounts and when consumed probably contribute to the diet of grazing livestock. However, many are not taken by the grazing animals and thus are largely useless plants that are using nutrients, water and light that would grow plants of higher value. In addition to the low palatability of some weeds, many are annual plants that fluctuate more widely in production with adverse weather than the more desirable perennial plants.

According to the 1950 census, there are 145 million acres of pasture land in the 12 North Central states, from Kansas to Ohio and northward; this is 36 percent of the land in farms. Forty percent of the pasture land is plowable pasture and about 50 percent of this had been plowed in the last seven years at the time of the census. The latter is assumed to be in improved pasture and to have a less acute weed problem. Conversely, about 60 percent of the pasture land is not plowable and here there is a great weed problem. It is in the non-plowable pastures, especially, that more efficient weed control methods are needed. They cannot be plowed and reseeded to improved pastures.

The losses from weeds in pastures are tremendous, and the losses vary greatly from pasture to pasture, making accurate estimates of losses difficult. In one pasture in Nebraska over 50 percent of the total production of plant material consisted of weeds (10, 11, 12). Here the average total yield of dry matter (including weeds) in the pasture, for the three years 1951–53, was 4214 pounds per acre. Of this, 2310 pounds were broad-leaved weeds and 701 pounds were weedy grasses. These weeds should be replaced with plants of higher value.

In general, for every pound of weeds grown in pastures the production of more desirable forage plants is reduced by about an equal amount. This broad generalization varies with moisture conditions and the weed and pasture species involved. Klingman and McCarty (10, 11, 12) found that the total production of dry matter in pasture treatments, where most of the broad-leaved weeds were controlled, averaged 92 percent that of the weedy check. Here grasses were the only desirable pasture plants present. In such pastures the substitution of legumes in the space occupied by weeds might well have increased this to above 100 percent because of their vigorous habit of growth and because of the nitrogen fixation that occurs with legumes.

Much of the research in pasture management has resulted in means of controlling weeds as a by-product of research performed

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to obtain greater production. Nevertheless, there are tremendous and deplorable losses to weeds in pastures in the North Central Region. Too few farmers have adopted the improved practices available and such weeds as ragweed, *Ambrosia* spp.; marestail, *Erigeron canadensis* L.; snow-on-the-mountain, *Euphorbia marginata* Pursh.; ironweed, *Vernonia baldwinii* Torr.; vervain, *Verbena stricta* Vent.; yarrow, *Achillea millefolium* L.; goldenrod, *Solidago* spp.; asters, *Aster* spp.; wild garlic *Allium* spp.; and wild onion, *Allium* spp. are obvious in a large number of pastures in any state in the region. Less obviously present, but equally common, are the weedy grasses, which are mostly annuals and of low value for pastures. Notable are the weedy bromegrasses, *Bromus* spp.; wild barleys, *Hordeum* spp.; foxtails, *Setaria* spp.; crabgrasses, *Digitaria* spp.; and triple-awn, *Aristida oligantha* Michx. Also, there is much brush on pasture land. While brush occupies less acreage of pasture land than the other weeds, it is often a more difficult problem. Some of the common kinds are buckbrush, *Symphoricarpus* spp.; hazelbrush, *Corylus* spp.; locusts, *Robinia* spp.; elms, *Ulmus* spp.; oaks, *Quercus* spp.; persimmon, *Diospyros virginiana* L.; sassafras, *Sassafras variifolium* (Salisb.) Ktze.; and briars, *Rubus* spp.

CONTROL METHODS

Weeds in pastures must be attacked with all the means available if progress is to be made. The advances made to date, along with new approaches to the problem, must be fully utilized. For many years research in pasture improvement has been approaching this problem through management and cultural means. Studies have included renovation, plowing and reseeding to improved species, judicious grazing, fertilization and mowing. Usually the objective has not been weed control, but has been primarily that of increased production of high quality forage. Research in weed control should have that same goal. However, there is also reason for emphasis upon the control of weeds as the primary goal in research, since the control of unpalatable weeds by any means will result in greater production of useful forage, providing there are forage plants present and the method of control does not seriously injure the forage species. There is a need for improved methods of weed control to be used in combination with the improved pasture management methods that have been developed.

Plowing and Reseeding

The most efficient method of controlling many weeds is to create conditions that exclude them from the pasture by the vigorous and dense growth of forage plants. The quickest way to accomplish this is to plow and seed to an improved pasture mixture. This often entails considerable expense for cultivation, fertilizer and seed; however, the results will usually justify the expense, especially on land that can be plowed and used in rotation with other crops. Ahlgren et al. (4), in Wisconsin, found that plowing bluegrass sod and growing crops of corn, oats and an improved pasture mixture in

a six year rotation produced more forage in the four years in grass than was produced in the same six years on bluegrass pasture. In addition there were six tons of dry matter as corn and oats in the other two years. In such pastures most weeds are not usually a problem, although they may be a great problem during the establishment period. Plowing alone is effective in controlling many of the perennial weeds such as ironweed, vervain, goldenrod, asters, yarrow and many others (11). It is not effective against persistent weeds such as wild garlic, Canada thistle, or against brush such as persimmon.

This method of pasture improvement, and consequent weed control, has been accepted on only a limited acreage. Plowing is limited to land of gentler slopes and soils relatively free of rocks and other obstructions; thus it cannot be used on 60 percent of the pasture land. In addition, there are frequent failures in obtaining adequate stands (often because of weeds) and there is the high cost for tillage, seed and fertilizer usually required for success.

Fertilization

Fertilization may be helpful in controlling some weeds, but is ineffective on others. A number of weeds will be eliminated by the competition of grasses which will develop if an adequate lime and fertility level is provided. Although the addition of fertilizer to pastures is effective in controlling certain annuals, it is less effective for control of many of the perennials. Indeed it may favor some of the perennials and even some annuals unless accompanied by supplemental mowing or spraying practices. While minimum requirements for vigorous growth of forage plants are necessary if gains made by other weed control practices are to be held, it is doubtful that the use of fertilizer alone for weed control will give satisfactory results in many pastures.

It is essential that at least the minimum fertility needs for growing forage plants are met if any method of weed control is to be successful.

Renovation

Renovation practices have been shown to reduce stands of weeds and has resulted in increased yields of forage (6, 9, 14). Recently there has been interest in using herbicides to subdue weeds and other vegetation in connection with the renovation process. This is particularly promising in reducing the number of tillage operations required to properly renovate a pasture. Pasture renovation is often practical on land that cannot be plowed, but is primarily effective against annual weeds. If perennial weeds are a problem, supplemental treatments usually will be necessary for their control. In some instances their control should be undertaken before renovation is attempted. Where this approach is feasible the renovation treatments should be deferred until control of the persistent perennial weeds has been accomplished, especially if an herbicide injurious to legumes is to be used. There is usually considerable cost involved in successful renovation treatments and the benefits are often tem-

porary, especially with certain of the legumes that are used and under the grazing management usual on most farms. It would appear that additional studies of weed control methods to be used in combination with renovation practices are needed.

Mowing

Mowing for weed control has been widely recommended for control of weeds in pastures. It has been shown to be effective for control of certain annual weeds (10, 11, 12) and with proper timing effective for control of some perennials (2, 3), although more recent studies in Nebraska have shown the mower to be relatively ineffective for this use (10, 11, 12). Further studies of the effectiveness of mowing are indicated, and especially of the relative merits of mowing vs. herbicides.

Mowing has given good control of many annual broad-leaved weeds if done at about the bloom stage and providing they were sufficiently upright in habit of growth. Two years of mowing reduced annual ragweed 82 percent when the mowing was done July 1, but only 24 percent when the mowing was done two weeks earlier (10, 11). It is also effective on some weedy grasses if carefully timed. Finnerty (8) found that mowing weedy bromegrasses, about one week after the heads had emerged from the upper sheath, resulted in good control. Mowing earlier permitted subsequent emergence of panicles from young tillers. Mowing later failed to prevent production of viable seed.

It has been observed that mowing for weed control on farms often is not successful. Many farmers mow their pastures when it is most convenient to them and this is usually long after the optimum date for weed control. However, the appearance of the pasture is greatly improved by the mowing and lasts until the next growing season at which time weeds are again in great abundance. While this mowing cannot be classed as weed control, there may be other benefits such as removing obstructions to grazing, and improving the appearance of the pasture for about nine months.

Mowing done faithfully and at the proper time will keep brush from becoming a problem in pastures. Its effectiveness in eliminating brush varies with species, location and time of mowing. Many times mowing does not eliminate it but rather keeps it from getting any larger.

Timing is critical for the elimination of many woody plants, and the critical time varies with the species. For instance, buckbrush must be mowed early, in early May in Kansas, if control is to result (2, 3), while better results are obtained with many other species when mowed somewhat later, in June or July (2, 3, 5).

Clearing land so that mowing can be done may be a major expenditure. Abell (1) reported the time required on plots in a pasture too steep and too rocky to be plowed and reseeded and from which brush had to be removed before fertilization would be advisable was 80 hours in three years for cutting and 59 hours for burning (fire gun). Larson and Crumpacker (13) report over 30 hours for

cutting and getting rid of the brush in a pasture in Central Missouri. Bulldozers and other such mechanical means are somewhat less expensive but have disadvantages of denuding the soil, erosion of denuded soils and poor control of young sprouts.

After clearing the land, the practice of annual mowing will keep sprouts from again gaining dominance, but the time required for eradication is indefinite. With some species and in some locations a great many years may be required.

Herbicides

Estimates of acreages of pasture sprayed in the North Central States in 1953 totaled about ¾ million acres. This is about 0.5 percent of the total acreage of pasture and leaves a big field for expansion of this promising practice.

Herbicides are more efficient for the control of most broad-leaved weeds and brush than mowing or hand clearing. Effective control does not usually depend upon as critical timing as is needed with mowing, nevertheless, for many perennial plants there is a definite relationship between optimum time for mowing and optimum time for spraying (11, 12). This is not essential for annual weeds and because of less critical timing requirement, more kinds of weeds may be controlled with a single spraying application than will be controlled with one mowing. In addition, ground that has rocks, stumps and other obstructions can be more easily sprayed than mowed. Also certain weeds with a low growing habit cannot be controlled at all by mowing but may be controlled effectively by herbicides.

In an experiment in Nebraska comparing spraying and mowing for weed control, broad-leaved perennial weeds were reduced about 35 percent by three years of mowing and about 70 percent by spraying with one pound 2,4–D ester (isopropyl and butyl) per acre each year (12). The amount of forage (dry matter) eaten by cattle on these same pastures was 1650 pounds on the sprayed pasture and 1340 pounds on the mowed as compared to 1124 on the untreated. That is an increase in forage consumed of 47 percent for spraying and 19 percent for mowing when compared to the untreated pasture. Benefits of weed control were also shown by changes in stands of grasses. Desirable grasses were increased in basal density an average of 32 percent above the check by mowing and 35 percent by spraying. Conversely, the basal density of weedy grasses was decreased 50 percent by mowing and 31 percent by spraying.

Herbicides may injure some of the legumes in the pasture, although legume species vary in their reaction to herbicides. More studies are needed to determine the extent of injury, and the possibilities of timing the application of herbicides so that a minimum of injury will result while giving satisfactory weed control. Also, legumes are often absent from weedy pastures and thus their reaction need not be considered when planning the spray treatments.

Ladino clover and white clover tolerate 2,4–D after they are established, although their growth rate is temporarily reduced. It is usually not safe to spray established alfalfa, sweet clover or red clover.

Elder and Erickson (7) reported that Korean lespedeza tolerates ½ pound 2,4–D amine or MCPA amine when applied after the six-leaf stage with only 10 to 15 percent reduction in yield when compared to weed-free, untreated lespedeza. This rate of treatment controls many of the weeds that are a problem. When 2,4,5–T was applied the lespedeza was eliminated.

Combinations of spraying and mowing have not been explored sufficiently in pasture weed control. In some areas of the region mowing is desirable for reasons other than weed control, namely to encourage more uniform grazing and to favor development of the associated legumes. Where such practices are useful the potential for herbicides has not been determined.

Herbicides may be used to kill or weaken existing vegetation so that more desirable species may be introduced (chemical renovation). These are of particular value on areas that are too steep or are difficult to cultivate for other reasons, and where the need to introduce more desirable forage species is acute. They may also be useful as supplemenal treatments to keep weeds in check while forage plants are becoming established. For example, recent work (unpublished) in Missouri gives indication that herbicides may be useful in establishing birdsfoot trefoil. Herbicides have been used successfully for control of grassy weeds in birdsfoot trefoil establishment during the last three years. However, much is yet to be learned before the value of this approach will be determined.

CONCLUSIONS

Though our weed control research in pastures is finding and evaluating more efficient herbicides and methods for controlling individual weeds, the job is not complete when that information is obtained because we must also compare the new methods with the old. Evaluation must be made of how they can be worked into the pasture systems found on the farms and what are the relative costs, relative returns, safety and convenience of the newer methods? It is here that too little research is now being expended. Research in weed control in pastures, as pasture management, had been underway for a long time before discovery of the newer herbicides. The new herbicides must be worked into pasture management as "tools", if we are going to reduce the tremendous losses from weeds now occurring in pastures in the North Central Region.

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Survival of Big Sagebush of Different Ages after Treatment with Selective Herbicides

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Big sagebrush (*Artemisia tridentata,* Nutt.) is such an aggressive increaser that most of the formerly grassy ranges of the intermountain and northwest regions have long since acquired a sagebrush aspect. A suggestion as to the impact of this change upon grazing capacity is apparent from a three-year study in northern Nevada. An average reduction in yield by 20 native and exotic grasses and weeds of about 70 per cent was shown under limited competition with big sagebrush (12).

Those ranges with good remnants of native grass can be restored without seeding if brush can be controlled. Ranges that cannot be restored through brush control and intensified management should be considered for reseeding.

Brush control is necessary before seeding and sometimes after seeding, depending upon factors that are not fully understood at present.

It is recognized that the problem of sagebrush control has been extensively studied in other states. The present study was begun in 1953 to try to reconcile seemingly contradictory information from other locations and to confirm more uniform results under yet another environment, including artificially seeded range.

Nearly all published work on this problem has helped describe more closely the essential factors for successful sagebrush control. Herbicidal formulations, solvents, rates, volumes, and dates have been sifted and narrowed until a group of general recommendations has become part of the stock-in-trade of range technicians throughout the West. Cornelius and Graham (3) showed how selective herbicides may be used to prepare the way for seeding. Following several years of work in the yellow pine zone of northern California, they narrowed their recommendations to butyl ester of 2,4–D at 1 pound per acre. Those authors pointed out the advantages of chemical control over mechanical methods. Possibilities of gearing spray operations to early or late spring growth were shown.

The same year, 1951, Hull and Vaughn (6) published their first year's results from an investigation in a much different environment in Wyoming. One year later, results of their two years of study were published. Periodicity of plant development was emphasized as the clue to the time to spray for the best kills of sagebrush. Butyl ester of 2,4–D was very effective in killing sagebrush. However, 2,4,5–T at half the acid equivalent rate was a little better than 2,4–D. An interaction between formulation and stage of plant development was found. Sagebrush plants of all ages appeared to respond alike.

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Results of experiments in Oregon by Hyder (7) were published in 1953. The experimental conditions and several of the factors studied appear to be more like those of the present experiment than others reported. Young mature brush appeared to be more resistant to herbicides than old mature brush, but not consistently so. Sagebrush was easier to kill with herbicides in May than in other months. Sandberg bluegrass *(Poa secunda)* was recommended as the best indicator plant. The end of the period of susceptibility appeared to be marked by drying of the bluegrass leaves. On a dry site, the period of highest kill of sprayed sagebrush was earlier than on a moist site.

The following year, 1954, results of airplane spraying of sagebrush at a high elevation in Wyoming were published by Bohmont (1). Single high rates of application and repeated treatments both resulted in high kills. Control obtained by mid-June applications of 2,4–D was found to be better than with similar applications of 2,4,5–T. Conventional and low volatile esters were equally effective.

Hyder and Sneva (8), in 1955, published a second report on the Oregon work. Sandberg bluegrass was again found to be a reliable indicator. Maximum mortality of sagebrush resulted from spraying during the period which began with emergence of the bluegrass panicles and ended with the loss of green color as the grass matured. The results showed 2,4,5–T to be more effective than 2,4–D earlier, but less effective later, in the recommended period. Oil as a solvent was no better than water, even at low volume applications. Five to six gallons of spray solution per acre were thought necessary for thorough coverage.

METHODS OF STUDY

Two contiguous areas were found in central Elko County, Nevada, where old and young stands of sagebrush could be studied side by side. The latitude is 40° 42′ N., the longitude, 115° 34′ W., and the elevation, 5400 feet. The old stand was previously undisturbed except by normal grazing. No grazing by livestock was permitted during the experimental period. The sagebrush consisted of several size and age classes, the oldest being about four feet tall. The principle subdominants were *Poa secunda, Sitanion hystrix, Phlox spp., Balsamorhiza saggitata, Agropyron riparium, Oryzopsis hymenoides,* and *Chrysothamnus viscidiflorus* var. *elegans.*

The adjacent area had been plowed and seeded in 1944 to crested wheatgrass *(Agropyron desertorum)*, western wheatgrass *(A. smithii)*, and bulbous bluegrass *(Poa bulbosa)*. It had been grazed without control in 1945 and 1946, during which time many brush seedlings became established.

Precipitation and temperature for the nearest Weather Bureau Station at Elko, Nevada, are presented in Table 1 to permit comparison of the treatment year with the normal year.

The year 1953 was somewhat drier and considerably cooler than normal. May was especially cold. Local people observed that spring was 2–3 weeks late in arriving.

Table 1. Climatological data for Elko, Nevada.

Year	Total precipitation				Mean daily temperature				Frost-free days
	Annual	April	May	June	Annual	April	May	June	
Normal	9.13	0.93	0.95	0.70	46.4	44.6	53.0	60.3	103
1953	7.04	0.59	1.05	0.53	45.7	42.2	45.1	57.9	70

Each plot layout was 200 × 280 feet, providing for 4 replications of each treatment on plots 20 × 50 feet. A split plot design was used in assigning treatments. Herbicides used were 2,4–D (2,4–dichlorophenoxyacetic acid) as the butoxyethanol ester, 2,4,5–T (2,4,5–trichlorophenoxyacetic acid) as the isopropyl ester and shale oil. The 2,4–D and 2,4,5–T were each mixed with diesel oil and shale oil and sprayed at the rate of three gallons per acre. The unfortified shale oil was sprayed at the rate of 50 gallons per acre. The shale oil, which was obtained by the Bureau of Land Management, had the following specifications: Gravity A.P.I., 16.8; specific gravity .9540; I.B.P., 508° F.; olefins, volume 14%; aromatics, volume 69%; paraffins and naphthenes 17%. Because they cost approximately the same, one pound acid equivalent of 2,4,5–T and 2 pounds of 2,4–D were applied per acre. These chemicals were applied at three dates, April 18, May 18, and June 18, 1953, excepting those having shale oil as a carrier, which were used only on the May date. The shale oil alone was sprayed from a back-pack sprayer. The low gallonage materials were put on with the sprayer described by Jensen and Robocker (9). The rate of output was such that the plot was traversed lengthwise, sidewise, and diagonally, insuring complete coverage. In order to avoid drift, all spraying was done within 2–3 hours of daybreak when the mountain-valley breeze system was at rest.

Certain physical conditions prevailing at the three times of spraying may have influenced the results (Table 2). Soil moisture to a depth of 2 feet was very similar in the 2 stands of sagebrush. An increase in moisture in the second foot and a decrease in the first foot in June reflected monthly precipitation shown in Table 1.

It is noteworthy that April treatments were applied under essentially winter conditions. The hoar-frost was heavy and the soil surface frozen. The lateness of spring is borne out also by observations of plant development (Table 3).

Table 3. Plant development records at three monthly periods of treatment, 1953.

Species	April 17	May 15	June 18
Artemisia tridentata	Growth beginning	Growth ¾–1½ in.	Growth 2–3 in.
Chrysothamnus viscidiflorus var. *elegans*	Growth beginning	Growth 1¼ in.	Growth 2½–3 in.
Agropyron desertorum	Growth 5 in.	Leaves 10 in.	Heads mostly out
Poa secunda	Growth 1½ in.	Heads emerging	Post-bloom, drying
Sitanion hystrix	Growth 5¼ in.	Leaves 7 in.	Flowering

Table 2. Physical factors prevailing at the time herbicides were applied.

Date 1953	Air temp. °F.	Precip.	Light	Air movement	Humidity	Soil temp. °F at 4 in.	Soil moisture percentage at various soil depths					
							Old brush stand			Young brush & grass		
							0–6	6–12	12–24	0–6	6–12	12–24
4/17.....	30–50	Rain & snow 4/16	Cloudy and clearing	Calm at 6:00–8:00 a.m.	Heavy frost	36	19.5	16.0	18.2	20.4	19.7	15.2
5/15.....	30–50	Shower in evening of 16th	Cloudy and clearing	Calm at 6:00–8:00 a.m.	Frost 16th 5 a.m.	43	9.1	11.6	10.0	9.6	11.2	8.7
6/18.....	50–60	None	Fair	Calm at 6:00–8:00 a.m.	Low	60	5.5	8.0	12.6	8.0	10.6	13.1

Table 4. Averages and ranges in numbers of sagebrush plants per plot by size classes before treatment.

Size class	Old stand		Young stand with crested wheatgrass	
	Avg.	Range	Avg.	Range
Shrubs more than 4 inches tall per 1/100 acre	33.6	14–87	71.9	27–136
Shrubs less than 4 inches tall per 30 square feet	25.2	0–127	1.1	0–16

The variation in stands in the experimental area is shown in Table 4. Plants less than 4 inches tall represent counts on 3 belt transects one foot wide across the middle 10 feet of the plot; i.e., 30 square feet. The larger plants were counted on plots 43.6 feet × 10 feet (1/100 acre) in the center of the 20 foot × 50 foot treated plot.

There were too few sagebrush plants less than 4 inches tall in the stand of young brush and crested wheatgrass to permit valid comparisons. These plants are therefore given no further consideration.

RESULTS

The results of treatment on the larger sagebrush plants in the young and old stands are given in Figure 1. These data are based on plant counts before and 13–16 months after treatment. They are expressed as per cent survival with a plant counted as a survivor if as much as one twig remained alive. Table 5 summarizes the results of the analysis of variance for the effects of treatment on the different stands and size classes. Since, on inspection, the means and standard deviations appeared to be proportional, the data were converted to logarithms before analysis as suggested by Snedecor (13). All tests of significance were applied to the converted data. As seen in Table 5, there were no significant relationships among the treatments applied to the small brush in the mature stand. This was due to the high variability caused by the method used for estimating survival, the relatively few plants counted in many plots, growth into the larger size-class between counting dates, and the damage to these small plants caused by the larvae of a moth, *Aroga websteri*. Because of the lack of significance of the results, the data are not presented in Figure 1. However, the actual differences in survival were large. The treatments that appeared to be effective

Table 5. Significance of factors in tests comparing three herbicides at three dates on three age-size classes of big sagebrush.

Factors	Large brush in mature stand	Small brush in mature stand	Large brush in young stand
Dates	n.s.	n.s.	n.s.
Treatment	**	n.s.	**
Treatment x Date	**	n.s.	n.s.

**Significant at the 1 per cent level.

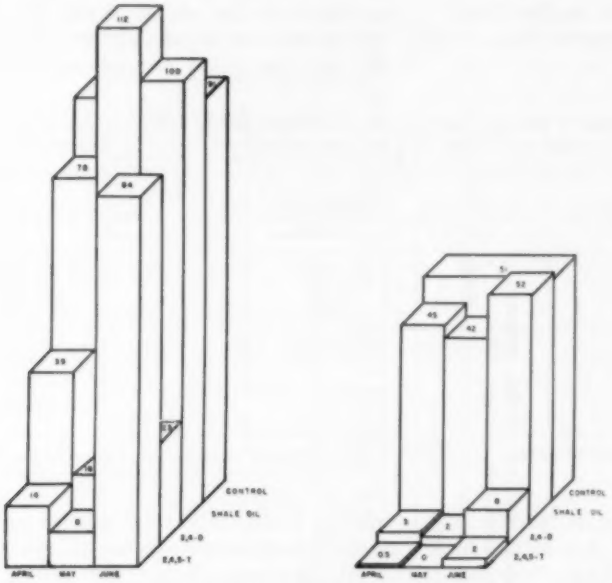

Figure 1. Average percentage survival of two age classes of big sagebrush a year after being sprayed with 2,4–D at 2 lb/A, 2,4,5–T at 1 lb/A or shale oil at 50 gal/A at three dates. Left, shrubs more than 4 inches tall in an old mature stand. Right, young shrubs more than 4 inches tall in crested wheatgrass.

were 2,4–D applied in either May or June (4 and 10 per cent survival, respectively) and 2,4,5–T applied in April (16 per cent survival). The untreated controls averaged 60 per cent survival.

Table 6 gives the significance of a number of treatment comparisons involved in the test on the larger brush in the mature stand. Comparisons between treatment means at a given date level were made by means of the Duncan multiple range test (4). Comparisons between date means at a single treatment level and date means at different treatment levels were made by the approximate method suggested by Cochran and Cox (2). In this table the significance level is given for positive treatment differences only. Where the treatment differences are negative, where the treatment differences are nonsignificant, and where the comparisons cannot be made, dashes are inserted. Because the treatment × date interaction in the experiment involving the young sagebrush stand was not significant, no such table was prepared for those results. In this latter test, the overall effect of treatment was highly significant with 2,4,5–T superior to 2,4–D at the 5 per cent level and each of these herbicides superior to shale oil or the untreated control at the 1 per cent level. Shale oil treatment did not differ significantly from the untreated controls.

A comparison of diesel oil and shale oil as carriers of 2,4–D and 2,4,5–T was made on the May date. The results of these trials are

Table 6. Significance of differences between mean survival of old, mature big sagebrush plants when treated with three chemicals at three dates.

Date of treatment	Comparison	Date of treatment											
		April				May				June			
		Ck.	2,4-D	2,4,5-T	S. O.	Ck.	2,4-D	2,4,5-T	S. O.	Ck.	2,4-D	2,4,5-T	S.O.
April	Check significantly better than	—	—	—	—	—	—	—	—	—	—	—	—
	2,4-D significantly better than	.05	—	—	.05	—	—	—	—	—	—	—	—
	2,4,5-T significantly better than	.01	.01	—	.01	.01	—	—	.01	.01	—	.05	.01
	Shale oil significantly better than	—	—	—	—	—	—	—	—	—	—	—	—
May	Check significantly better than	—	—	—	—	—	—	—	—	—	—	—	—
	2,4-D significantly better than	.05	—	—	.05	.01	—	—	.01	.01	—	.05	.01
	2,4,5-T significantly better than	.01	—	—	.01	.01	—	—	.01	.01	—	.01	.01
	Shale oil significantly better than	—	—	—	—	—	—	—	—	—	—	—	—
June	Check significantly better than	—	—	—	—	—	—	—	—	—	—	—	—
	2,4-D significantly better than	.05	—	—	.05	.05	—	—	.01	.01	—	.01	.01
	2,4,5-T significantly better than	—	—	—	—	—	—	—	—	—	—	—	—
	Shale oil significantly better than	—	—	—	—	—	—	—	—	—	—	—	—

given in Table 7. Shale oil was inferior to diesel oil as a carrier when applied to the larger, mature brush, and showed no superiority on either of the two other age-size classes.

Table 7. Per cent survival of big sagebrush of differing age-size classes after treatment with two herbicides each in two carriers in May.

Material applied	Large plants in mature stand, class A	Seedlings in mature stand, class B	Large plants in young stand, class C
2,4-D + shale oil	50.5	40.5	2.6
2,4-D + diesel oil	15.6	4.1	0.5
2,4,5-T + shale oil	53.2	62.1	0.0
2,4,5-T + diesel oil	8.3	38.4	0.0
Factors	Significance		
Carrier	**	n.s.	†
Herbicide	n.s.	n.s.	†
Carrier x herbicide	n.s.	n.s.	†

†Not calculated because only five plots among the sixteen contained any surviving plants.
**Significant at 1% level.

In general, the well-established plants of the young stand were more susceptible to the herbicides than shrubs of either size class in the old stand. The small plants in the old stand were consistently reduced by 2,4–D more than the older plants; but 2,4,5–T allowed higher mean survival in the small size class.

DISCUSSION

The design of the experiment made it possible to consider sagebrush survival in relation to 3 growth stages, 3 age or vigor classes, 3 herbicides, and 2 solvents. The second solvent, shale oil, was tested at the May date only.

As a result of the thorough study by Hyder, et al. (8), *Poa secunda* is gaining general acceptance as an indicator of time of spraying. They recommended that growth regulators be applied to big sagebrush after emergence of the heads of this grass and not after its green color is half gone. Our results appear to advance this period slightly. From Figure 1 and the discussion of results above, it is seen that kills of 86, 84, and 99.5 per cent were obtained with 1 pound of 2,4,5–T on three classes of brush in April. Heads of *Poa secunda* were to emerge a month later, the leaves being only 1⅓ inches long at the time (Table 3). This result is at variance with the finding that "In stands of mixed ages the younger plants are least injured," but does agree regarding stage of maturity, "...when sagebrush is actively growing," by Pechanec, et al. (10). Increased resistance to both growth regulators was shown by all classes of sagebrush from May to June. *Poa secunda* had completed flowering and was drying up at the time of the June spraying. Sagebrush had 2–3 inches of new growth, despite lower than normal temperatures and precipitation. If development of associated plants or current growth of the sagebrush are reliable indicators of suitable periods, it seems reason-

able to predict satisfactory control of sagebrush as early as April 1 in a normal season at similar latitude and elevation.

The satisfactory kill by April treatments may have been due in some way to the presence of hoar frost on the foliage. The nozzle discharged a fog-like spray of the low gallonage materials. The nature and value of the physical phenomena involved in transmission of the chemical fog particles to the leaf surfaces upon melting of the frost is a matter of conjecture.

In attempting to reconcile results of this study and one made previously (11), a negative correlation is apparent. Although sagebrush roots were found to grow most actively in the summer after the soil had warmed, the translocated herbicides used in this and other similar experiments tended to become less effective at that season. This needs further study with attention to soil temperature, moisture and periodicity of plant development.

Age classes

The three classes were; A, old, mature shrubs up to 4 feet tall and others down to 4 inches tall; B, suppressed juveniles and seedlings less than 4 inches tall under the mature stand; and C, shrubs 4–15 inches tall that had sprung up in the crested wheatgrass during the preceding 10 years. Classes B and C proved to be much more susceptible to 2,4–D at all dates than class A. However, 2,4,5–T was more effective on class C throughout the spring season than 2,4–D, but was less effective on class B. While all three classes were most susceptible in May, class C was effectively controlled each month by both formulations. Class A was not well controlled in April by 2,4–D nor in June by 2,4,5–T. These variations are somewhat in disagreement with results reported by Hull, et al. (5).

The general mortality which occurred regardless of treatment was considerably less in class A. This mortality was due mostly to attacks by the larvae of a moth, *Aroga websteri*. The higher mortality among the shorter plants is probably accounted for by the gradual upward movement of the insects. The larvae pupated before reaching the tops of many of the taller shrubs.

Average survival percentages of the control plots varied with size and age of stand. Old mature shrubs survived 91 per cent; their understory juveniles, 60 per cent; and the young stand with wheatgrass, 51 per cent.

Formulations and carriers

Low volume application of one pound of 2,4,5–T appears more effective than 2 pounds of 2,4–D early in the spring; i.e., mid-April. Two months later, 2,4–D was more effective. There is a time midway between the beginning and the end of the spray period when either formulation or a mixture of the two is recommended.

Although no such mixture was used, the results suggest that optimum results would probably be obtained from mixing esters of 2,4–D and 2,4,5–T, in diesel oil and applying when plant development is similar to that shown for May in Table 3.

Shale oil of the specifications used cannot be recommended be-

cause it was not more effective than diesel oil as a carrier and was more disagreeable to handle. Alone, at 50 gallons per acre, shale oil was ineffective as an herbicide. Inasmuch as water has been found satisfactory as a carrier elsewhere (5), it is unlikely that a price differential will ever justify use of shale oil on sagebrush.

SUMMARY

Two stands of big sagebrush in Elko County, Nevada, were sprayed with two growth regulators at three dates. The stands were of widely different ages. The interval between dates was one month. The growth regulators were esters of 2,4–D and 2,4,5–T. The carrier was diesel oil; but on the middle date in May, a second carrier, shale oil, was also used. Shale oil alone at 50 gallons per acre was used unfortified at all three dates.

In all but one case, significant treatment differences were found. There were interactions between date (stage of plant development) and spray material, and between age-size classes of brush, date and material. The latter could not be analyzed or fully interpreted. Evidently, big sagebrush can be controlled satisfactorily at the beginning of its growth in the spring by thorough application of certain growth regulators on sites with soil and rainfall that are favorable for crested wheatgrass.

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Quality of Tomato Fruit as Affected by Sodium 2,4,5–Trichlorophenoxyethyl Sulfate[1]

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INVESTIGATIONS during the past 3 years have established sodium 2,4,5–trichlorophenoxyethyl sulfate, hereafter referred to as 2,4,5–TES, as a potential herbicide for control of weeds in tomatoes. The chemical has been succesfully applied just after the last cultivation. The material may be applied either as a basal-directed spray or an overall spray in tomatoes since it becomes phytotoxic only after contact with the soil. Its promise as a herbicide suggests the need for a critical evaluation of possible effects on quality of the fruit. Three measures of quality which may be affected include taste, chemical composition, and malformations such as cracking, blossom-end rot and seedlessness.

The nature of cracking suggests that it may be affected by plant growth modifiers. The two types of cracking, radial and concentric, originate from the stem end of the fruit. It has been sugested (6) that the ovary wall tissues at the stem end of the fruit contain more water than tissues at the stylar end. When the plant is exposed to sudden additional quantities of water, the cells in the ovary wall at the stem end cannot enlarge rapidly enough under the influx of water and cracking results. Plant growth modifiers could conceivably have an effect on cracking since they are known to influence water relations (7, 8). Protopectin, has been thought to occur (6) in greater quantities in ovary wall tissues of the stem end than the stylar end of the tomato fruit. At maturity the decomposition of protopectin in the stem end tissues may be the cause of cracking. Plant growth modifiers might possibly affect the decomposition of protopectin and thus affect cracking.

The effects of 2,4–D on plant composition suggest possible effects of 2,4,5–TES on composition of tomato fruit since the active decomposition product of 2,4,5–TES is closely related to 2,4,5–T. Numerous studies have shown that 2,4–D and related compounds may alter the composition of plants. Most commonly nitrogen (7, 13, 16, 19) and phosphorus (5, 11, 15) are decreased in the leaves and increased in the stem and roots. Carbohydrates are usually decreased in all parts of the plant although decreases are relatively less in root than in leaves (14, 20). Young fruit and expanding leaf portions of treated plants were reported as having greater quantities of carbohydrates than controls (12, 13); it was suggested that these plant parts had an increased absorption capacity for carbohydrates. Dry matter is generally decreased, with the loss in leaves relatively greater than that in roots (13, 17, 20). Reports in respect to growth modifier effects

[1]Cooperative investigations between the New Jersey Agri. Exp. Sta. and the Field Crops Research Branch, ARS, U.S. Dept. of Agriculture. Paper of the Journal Series, New Jersey Agri. Exp. Sta., Rutgers University, New Brunswick.

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on potassium, sodium, magnesium, and other elements are limited. One group of investigators (16) did, however, report losses of potassium in tops of rape and tomato and increases in roots of tomato from MCPA. The same workers found no effect on potassium in oats, nor in these species were there any effects on magnesium, calcium, sodium, manganese, copper, and iron.

The present investigation was initiated to evaluate the effect of 2,4,5–TES on quality of tomato fruit. Three measures of quality were used, namely the extent of cracking and other readily observed malformations, the taste of juice, and the chemical composition.

MALFORMATION OF FRUIT

Materials and Methods

Tomatoes var. Rutgers were transplanted May 18, 1955 to a Sassafras sandy loam soil. A randomized block design with 5 replications was used. Each plot was composed of 2 rows of 6 plants spaced 3½ feet within and between rows. Applications of 2,4,5–TES were made 8 weeks after transplanting at 3 and 6 pounds per acre. Since 2,4,5–TES is activated in the soil, the spray was directed to the soil to obtain maximum quantities of activated chemical. After treatment ½ inch of water was applied immediately to enhance the activation of the chemical by soil microorganisms. During the dry period from the time of application until August 8, approximately 1½ inches of water were added each week to meet the needs of the tomato plants.

A total of 8 harvests were made during the period August 9 to September 19. A map tracer (20) was employed to measure the length of radial and concentric fruit cracks and, in addition, the circumference of blossom end rot of harvested tomatoes. Measurements were recorded in centimeters per pound of fruit. A penetrometer with a point diameter of 0.6 millimeters was used to measure skin strength of fruit. It was thought that cracking might be correlated with skin strength (9). Measurements were recorded in grams pressure required to penetrate the skin. Blossom end rot data were obtained from the first 4 harvests. A drought prior to the third harvest provided conditions conducive to rot. Fruit cracking data were obtained from harvests 3, 4, 5, and 6. Heavy rains during this period accentuated cracking. At each harvest observations were made of other fruit quality factors such as sun scald, other exterior malformations, seedlessness, and irregular veining of interlocular walls.

Results and Discussion

Table 1 illustrates that both rates of 2,4,5–TES resulted in significant increases in blossom end rot of harvested fruits, and that 6 pounds per acre caused highly significant increases. This suggests that 2,4,5–TES has some influence on water relations of the plant. The increase in blossom end rot may have been partially due to root injury from the chemical which restricted water uptake. Root injury from soil applications of growth modifiers is commonly ob-

served. On several occasions dry periods were conducive to translocation of water from fruit which is known to accentuate blossom end rot.

Table 1. Tomato fruit cracking and blossom end rot as affected by applications of 2,4,5–TES. 1955.

Pounds of 2,4,5-TES per acre	Centimeters per pound of fruit	
	Blossom end rot[1]	Cracking[2]
None	3.3	64.2
3	6.7	68.1
6	8.3	76.7
L.S.D. 0.05	3.2	8.7
0.01	4.2	11.5

[1]Recorded from harvest 1–4.
[2]Recorded from harvest 3–6.

Preliminary quality studies during 1954 suggested an increase in cracking from 2,4,5–TES, particularly with the highest rate used of 5 pounds per acre. The data were recorded as percentage discard fruit of total fruit harvested. Percentage discard for no treatment, 2½ and 5 pounds of 2,4,5–TES per acre, was 46.2, 48.1, and 54.3 respectively. Cracking was also increased by 2,4,5–TES in 1955. Table 1 reveals that although 6 pounds caused a significant increase in cracking in 1955, 3 pounds caused no significant increase.

Measurements of skin strength during harvest 3, 4, and 6 showed no significant effect of treatment. The pressure required to puncture the skin was 101.7, 104.1, and 104.2 grams for no treatment, 3 pounds, and 6 pounds of 2,4,5–TES respectively. These figures represent averages of 5 replications per harvest for 3 harvests. Accurate penetrometer recordings were difficult to obtain since all fruit were seriously cracked. This may account for the absence of a significant correlation between skin strength and cracking.

Visual observations of fruit produced in 1954 suggested that 2,4,5–TES, occasionally caused other exterior malformations, seedlessness, and irregular veining of interlocular walls of fruit. During 1954 harvests 1 and 2, application of 2½ and 5 pounds of 2,4,5–TES caused 15 to 20 percent seedless fruit compared to 5 percent from untreated plants. Observations during 1955 revealed no material effect of 2,4,5–TES on exterior malformations, other than rot and cracking.

TASTE OF JUICE

Materials and Methods

Fruit samples were taken for subsequent taste analyses on 3 harvests of the 1955 test: August 4, 10 and September 19. The fruit was processed to tomato juice by the Food Technology Department of Rutgers University. After storage for 6 months flavor evaluations of juice were made by comparison with the uncoded check sample which had been grown under conditions comparable to the test samples. These evaluations are expressed in terms of their similarity

to or difference from the untreated sample. A flavor evaluation of "similar" means that the panel score of that treated sample does not differ from the rating of the check sample by more than the least significant difference between panel scores for all samples treated with the materials being tested.

Each judge also expressed his personal opinion on the acceptability of each sample. The panel rating of acceptability is not, however, to be construed as reflecting general consumer preference.

Panel judgements on each set of samples were analyzed statistically to ascertain whether flavor differences were detectable.

Results and Discussion

The chemical had no discernible effect on the taste of fruit. Flavor evaluations indicated that the taste of fruit harvested from plants treated with 3 or 6 pounds of 2,4,5–TES were similar to that of the untreated sample. All except one sample from 6 pounds of 2,4,5–TES harvested on August 4 were rated 100 per cent acceptable. This is of particular significance in light of results which showed that 2,4,5–TES had a definite effect on observable characteristics of fruit. Taste perhaps, may not be related to the other quality factors measured.

CHEMICAL COMPOSITION OF FRUIT

Materials and Methods

Tomatoes var. Rutgers were transplanted June 2, 1954. The plot design was a split-plot with 3 replications. The 2,4,5–TES and a diethanolamine derivative were applied at rates of 2½ and 5 pounds per acre 3 and 8 weeks after transplanting. Only fruit from the late treatment are considered in the present report since plants in the early treatment were damaged considerably by the herbicide. Fruit samples for chemical analyses were taken on September 15 and 30, which was approximately midway in the harvest period. Each sample was ground in a commercial food chopper, lyophilized, and finally ground in a Wiley mill.

The dried samples were analyzed for total nitrogen, phosphorus, potassium, sodium, total acids, and total carbohydrates. The Kjeldahl method of nitrogen determination was employed (2). Phosphorus, potassium, and sodium were determined by the method of Toth, et al. (18). Total carbohydrates were determined by the method of the American Association of Cereal Chemists (1) supplemented by the method of Johnson (10). Total or titratable acids were determined by the method of the Association of Official Agricultural Chemists (3). Percentage dry matter was determined by weighing a portion of each fresh sample, heating the sample at 90°C. until dry, then reweighing it. The majority of the data were recorded as percentages of the component in 1 gram of dried material.

Results and Discussion

The effects of the treatments on chemical composition of the fruit are shown in Table 2. The data presented here represent September

15 and 30 harvests. Five pounds of either chemical tended to increase nitrogen although the increase was not significant. Nitrogen content was not affected by 2½ pounds of either chemical.

Table 2. **Composition of tomato fruit as influenced by 2,4,5–TES and its diethanolamine derivative. 1954.**

Pounds of chemical per acre	Percentage in dried fruit				Pct. dry matter in fruit	Total acids[1]		Total carbohydrates[2]
	Nitrogen	Phosphorus	Potassium	Sodium		Sept. 15 harvest	Sept. 30 harvest	
None	1.54	0.708	8.80	.0624	4.96	24.98	26.20	43.5
2,4,5-TES 2½	1.55	0.632	8.90	.0696	5.28	24.22	25.77	42.5
5	1.60	0.633	8.20	.0696	4.90	25.07	22.28	41.8
2,4,5-TES diethanolamine								
2½	1.52	0.657	8.70	.0725	5.06	25.32	25.47	43.8
5	1.64	0.689	8.60	.0733	4.55	25.98	22.61	43.5
Av. all treated	1.58	0.653	8.60	.0713	4.95	25.15	24.03	42.9
L.S.D. 0.05		0.049		.0069	0.45	2.57	2.57	
0.01		0.065		.0099	0.60	3.41	3.41	

[1]ml 0.1 normal NaOH titrated for 1 gm. dry sample.
[2]mgm carbohydrates per 1 gram dry sample.

All treatments decreased phosphorus although the reduction with 5 pounds of the diethanolamine derivative of 2,4,5–TES was not significant. Applications of 2,4,5–TES resulted in approximately an 11 per cent reduction, which is consistent with reported effects of 2,4–D on phosphorus in other plant tissues discussed previously. The effect of decreased phosphorus and increased nitrogen in the present study might be explained partially by the work of Breon (4) which showed that a lack of phosphorus in the tomato often resulted in increased nitrogen. This relationship is only true for the 5-pound applications of the materials in the present study.

Potassium was unaffected by chemical applications.

All chemical treatments significantly increased sodium with the increase varying from 11.5 to 17.5 per cent. This increase in sodium was thought to be due to increased absorption of the element from the soil rather than to possible extraction from the herbicide molecule. The diethanolamine derivative, which has no sodium in the molecule, resulted in somewhat greater sodium content in the fruit than did 2,4,5–TES.

Total acids were significantly decreased in fruit from the Septem 30 harvest by 5 pounds of either chemical. The reduction with 2,4,5–TES was 13.7 per cent and that with the diethanolamine 15 per cent. Total acids in fruit were not affected from the September 15 harvest.

Total carbohydrates were essentially unaltered by chemical application. Five pounds of 2,4,5–TES, however, caused slight decreases in carbohydrates. These data agree with the thought of Marre and Murneek (12) and of Mitchell (13) that carbohydrates are not diminished in young leaves and fruit exposed to certain growth regulators because these tissues have greater absorption capacities than other tissues.

Percentage dry matter was essentially unaffected by chemical applications. However, when plants were treated with 5 pounds of the diethanolamine derivative of 2,4,5–TES they yielded fruit which contained significantly less dry matter than fruit from plants treated with 2½ pounds of either chemical. These data indicate again that high applications of these chemicals might have some effect on water relations.

SUMMARY

The effects of 2,4,5–TES on quality of the tomato were studied by measuring cracking and other physical characters of fruit, by evaluating taste of juice, and by determining chemical composition of fruit. The chemical was applied to tomatoes in the field at rates of 2½ to 3 pounds per acre and 5 to 6 pounds per acre. Applications of 2½ to 3 pounds per acre of 2,4,5–TES have successfully controlled weeds at this station. The following conclusions were based on these tests:

1. Cracking of fruit was unaffected by 3 pounds of 2,4,5–TES but was increased significantly by 6 pounds.
2. Blossom end rot was increased by 3 and 6 pounds of 2,4,5–TES.
3. Applications of 2,4,5–TES had no appreciable effect on interior veining or seedlessness.
4. Taste of juice was not altered by 2,4,5–TES.
5. Total nitrogen and total acids were unaffected by 2½ pounds of chemical. However, there was a tendency for nitrogen to be increased and total acids decreased by 5 pounds.
6. Phosphorus was decreased and sodium increased by all rates.
7. Chemical applications had no appreciable effect on total carbohydrates, potassium, or dry matter of the tomato.

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Tolerance of Asparagus to 2,4–D[1]

V. F. Bruns and W. J. Clore[2]

A number of investigators have tested 2,4–D (2,4–dichlorophenoxyacetic acid) for the control of weeds in asparagus. Several workers (1, 3, 4, 6) have suggested the use of 2,4–D at rates varying from one to three pounds acid equivalent per acre as a pre-emergence treatment after disking in the spring and again after disking at the end of the cutting season. Warren and Hernandez (5) applied 2,4–D at the rate of four pounds per acre on April 28 just after the asparagus bed was disked. The yield and appearance of the asparagus spears was not affected by the treatment. According to Ahlgren et al. (1), pre-emergence application of 2,4–D caused injury to the first emerging spears in some cases, but caused little permanent damage. These and other investigators found asparagus plants susceptible to foliage applications of 2,4–D and warned against spraying the fern.

Carew (3) indicated that 2,4–D applied to emerged spears could cause twisting and curling. Applications of 1.32, 1.98, and 2.6 pounds of the butyl ester of 2,4–D per acre were made by Alban and Keirns (2) in an established planting of asparagus immediately following the first commercial cutting on May 20. Canada thistle and pigweeds were controlled throughout the cutting season which covered a period of five weeks. The same quantities were applied to adjoining plots after the fourth cutting of asparagus. All treatments caused distortion of all asparagus spears that were above ground at the time of application. Approximately 50 per cent of the first cutting following treatment was unsatisfactory for marketing. However, subsequent cuttings appeared undamaged.

Many growers in the Yakima Valley of Washington have been troubled by infestations of weeds such as Canada thistle (*Cirsium arvense* L.) and morning glory (*Convolvulus arvensis* L.) in asparagus fields. Preliminary investigations at the Irrigation Experiment Station, Prosser, Washington, during 1949 and 1950 indicated that 2,4–D offered a possible means of controlling such weeds in asparagus, particularly during the cutting season. Studies reported herein were initiated to determine the tolerance of asparagus to yearly applications of an amine type of 2,4–D over a period of several years.

Materials and Methods

At the beginning of the 1951 cutting season, plots 5 x 109 feet in size were established in a 12-year-old asparagus field on a Sagemoor fine sandy loam soil. Previous observations and records of uniformity of vigor, stand, and yield of plants were utilized in selecting the

[1]Contribution of the Field Crops Research Branch, ARS, U. S. Department of Agriculture, and the State College of Washington, cooperating. Scientific Paper No. 1489, Washington Agricultural Experiment Stations.

[2]Agronomist, Field Crops Research Branch, and Horticulturist, State College of Washingon, respectively, Irrigation Experiment Station, Prosser, Washington.

experimental site. Normal, furrow-type irrigation was practiced throughout the course of the experiment.

Four treatments randomized within three experimental blocks were: (A) All emerged asparagus spears cut below the ground surface and the plots treated immediately afterwards with 2,4–D. (B) All emerged asparagus spears cut below the ground surface as in treatment (A) but the plots not treated with 2,4–D. (C) Only asparagus spears of marketable size cut below the ground surface and the plots treated immediately afterwards with 2,4–D. (D) Only asparagus spears of marketable size cut below the ground surface as in treatment(C) but the plots not treated with 2,4–D. Spears of marketable size were those that had reached a height of six inches or more above the soil surface. Therefore, with respect to cutting, treatments (C) and (D) simulated a normal harvesting operation on a commercial scale in which spears shorter than six inches above ground are left to develop and are harvested during subsequent cutting operations. In the discussion, the term "clean cut" designates cutting treatments in (A) and (B), while the term "normal cut" refers to cutting treatments in (C) and (D).

The treatments were made during the first week in June each year from 1951 through 1955. An alkanolamine salt of 2,4–D was used and applied at the rate of two pounds (acid equivalent) in 80 gallons of water per acre. The time and rate of application were chosen to coincide with those normally used to control noxious perennial weeds such as Canada thistle and morning glory. When necessary, plots were hilled or cultivated during the cutting season to eliminate competitive effects of grasses and other annual weeds.

The number and weight of untrimmed marketable spears from each plot were recorded daily throughout each of the cutting seasons. Yields were evaluated in terms of number of spears, weight per 100 spears, and tons per acre. The influence of the treatments on flavor characteristics were not evaluated in these studies.

RESULTS AND DISCUSSION

Although the initial 2,4–D treatments in 1951 were not made until June 6 and the last cuttings of asparagus spears were taken on June 16, the number and weight of spears from each plot were recorded throughout the cutting season. These data were useful in evaluating the results from subsequent treatments. The average annual yields for each treatment over the 5-year period are given in Table 1.

In 1952, the 2,4–D treatments were made according to plan on June 2. With the possible exception of plots clean cut but untreated with 2,4–D, the average yields from the plots under the different treatments were similar. No adverse effects from the 2,4–D treatments were apparent in the 1952 yields. An occasional spear on normal cut plots treated with 2,4–D showed slight curling or twisting before reaching marketable size. Following the 2,4–D treatment, emerged spears on these plots usually reached marketable size within one to four or five days.

The 2,4–D treatments in 1953 were made on June 3. Comparative

Table 1. The effect of 2,4–D on the yield of asparagus by treatments.

Treatment	Year	Untrimmed spear yields		
		No. per plot	Lb. per 100 spears	T./A.
(A) Clean cut 2,4-D at 2 lb/A	1951	1829	6.0	4.40
	1952	2239	5.8	5.20
	1953	2137	4.7	4.00
	1954	2425	3.9	3.92
	1955	2587	4.0	4.10
	Av.	2243	4.9	4.32
(B) Clean cut No 2,4-D	1951	1727	5.8	4.00
	1952	2009	5.9	4.70
	1953	1956	4.9	3.80
	1954	2173	4.0	3.60
	1955	2543	4.3	4.35
	Av.	2082	5.0	4.09
(C) Normal cut 2,4-D at 2 lb/A	1951	1799	6.2	4.40
	1952	2189	6.2	5.40
	1953	1999	5.2	4.10
	1954	2129	4.2	3.70
	1955	2476	4.5	4.45
	Av.	2118	5.3	4.41
(D) Normal cut No 2,4-D	1951	1990	5.7	4.50
	1952	2336	5.9	5.50
	1953	2094	5.1	4.30
	1954	2302	4.1	3.93
	1955	2331	4.4	4.08
	Av.	2211	5.0	4.46
L.S.D. within years		NS	NS	NS
C.V. range by years		7.4–13.9%	4.0–6.2%	8.6–16.5%

yields for 1953 were almost identical to those obtained in 1952. Analyses of the yield data showed no significant differences between treatments.

The 2,4–D treatments for the fourth year were made on June 2, 1954. Again, comparative yields for 1954 were almost identical to those obtained in previous years. The somewhat declining yields in 1953 and 1954 indicated possible seasonal variation as well as a need for nitrogen. The last application of nitrogen had been made in 1948 at the rate of 200 pounds per acre. A total of 266 pounds of nitrogen per acre (split application) was applied to the experimental area during 1954. Zinc ($ZNSO_4$) also was applied at the rate of 10 pounds per acre.

For the fifth year, the 2,4–D applications were made on June 3, 1955. As in previous years, no significant differences in spear yields between treatments occurred during the 1955 cutting season.

The yearly application of 2,4–D (alkanolamine) at the rate of two pounds per acre during the first week in June over a period of five consecutive years caused no significant reduction in yield of asparagus, regardless of whether all emerged spears or only the marketable spears were cut below the ground surface prior to the 2,4–D treatments. The asparagus fern and crowns appeared normal and undamaged on all plots at the end of the 5-year period.

SUMMARY

1. An alkanolamine salt of 2,4–D at the rate of two pounds per acre was applied to an established asparagus bed during the first week in June each year for five consecutive years.

2. On one series of plots, all emerged spears were cut below the the ground surface prior to the 2,4–D treatments. On a second series, only the spears of marketable size were cut below the ground surface before the 2,4–D treatments.

3. The 2,4–D treatments caused no significant reduction in yield as measured in terms of number of spears, weight per 100 spears, and tons per acre.

4. Fern and crowns appeared normal and uninjured on all plots at the end of the 5-year period.

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BRIEF PAPERS

A Possible Mechanism of Action of the Urea Type Herbicides[1]

ANSON R. COOKE[2]

THE herbicide, 3–(p–chlorophenyl)–1,1–dimethylurea (CMU), first reported by Bucha and Todd (1), is finding increasing uses in the field of weed control. The mechanism of action of this compound, however, is as yet unknown. One of the early symptoms of CMU toxicity is a chlorosis (2) which develops in both monocotyledonous and dicotyledonous species. Muzik et al. (5) have shown that while CMU will inhibit root growth, the primary toxic action of this compound is on the aerial portion of the plant. Cooke (3) showed that CMU brought about a large decrease in the sugar content of plants and suggested that the mode of action was through an interference with photosynthesis.

Preliminary experiments on the accumulation of starch in starved leaf discs exposed to sunlight indicated that CMU was interfering with photosynthesis. Similar leaf discs incubated with sucrose and CMU in the dark accumulated starch, indicating that CMU was acting somewhere before the formation of sugars. In an attempt to determine if CMU was actually affecting the photosynthetic mechanism, a study was made of the effect of this compound on the Hill reaction. This reaction was studied by a method proposed by Horwitz (4) in which Janus Green B is used as a Hill oxidant.

A suspension of chloroplasts was prepared from spinach leaves. The midrib was removed from the leaves and 25 g. of leaf material was homogenized for 30 seconds in a Waring blendor with 0.5 M sucrose. All operations were carried out in a cold room at 15° C. The homogenate was strained through cheesecloth and centrifuged at 2000 X g for 10 minutes. The supernatant fluid was discarded and the chloroplasts were washed twice in 0.5 M sucrose. After the final washing the chloroplasts were suspended in 40 ml of M/10 potassium phosphate buffer at pH 6.4 containing .06% KCl. Two and one half ml of this suspension were placed in a number of test tubes and an equal volume of CMU solution ranging in concentration from 2×10^{-4} M to 2×10^{-7} M was added. One half ml of 0.03% Janus Green B (54.1% pure) was then added to each tube and the tubes illuminated for 5 minutes. During the reaction the Janus Green B is reductively split forming a red colored compound, diethyl safranine. As any remaining Janus Green B is absorbed on the chloroplasts, the suspension may be centrifuged down and the density of the diethyl safranine determined on a spectrophotometer at 555 mu.

[1]Contribution from the Department of Botany and Plant Pathology, Agri. Exp. Sta., Oklahoma A. & M. College, Stillwater, Oklahoma.

[2]Present address: Chemical Department, Experimental Station, E. I. du Pont de Nemours and Company, Wilmington, Delaware.

The Hill reaction was completely inhibited by rather low concentrations of CMU as is shown in Table 1. At 10^{-6} M the reaction was almost completely inhibited and no red color was noted in the solution. A very slight amount of diethyl safranine was formed at 10^{-7} M. Phenylurethane, whose structure is somewhat like that of CMU, has also been shown to inhibit the Hill reaction (6). As CMU so effectively inhibits the Hill reaction at very low concentrations, it appears likely that CMU is inhibiting photosynthesis in the plant at the light end of the reaction.

Table 1. Effect of various concentrations of CMU on the Hill reaction as measured by the formation of diethyl safranine using Janus Green B as the Hill oxidant. Data expressed as optical density of solution.

Conc. of CMU	O. D. of solution
10^{-4} M	.016
10^{-5} M	.022
10^{-6} M	.043
10^{-7} M	.081
0	.640

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A Suggested System of Leaf Shape Classification[1]

A. C. BUDD and K. F. BEST[2]

IN STUDIES on the growth of weeds, especially in the seedling stage and also in plant taxonomy in general, the problem frequently arises of finding a precise and simple means of describing a leaf or a cotyledon. To overcome this problem, we are using a system which, for want of a better name, we call the Budd-Best system. Briefly it is a system of using three numbers and a descriptive term (Figure 1).

The first number is 10, a constant denoting the broadest width of the leaf, irrespective of size. The second number is the length from base to tip in relation to the greatest width; thus a leaf three times

[1]Contribution from the Forage Crops & Field Husbandry Divisions, Experimental Farms Service, Canada Dept. Agriculture, Swift Current, Sask.

[2]Range Botanist and Research Officer, Field Husbandry, Experimental Farms Service, resepectively.

as long as its greatest width would be 10–30. The third number gives the location of the widest part of the leaf when divided into 10 sections, the base being zero and the tip 10. This figure, together with one descriptive name, gives the leaf shape.

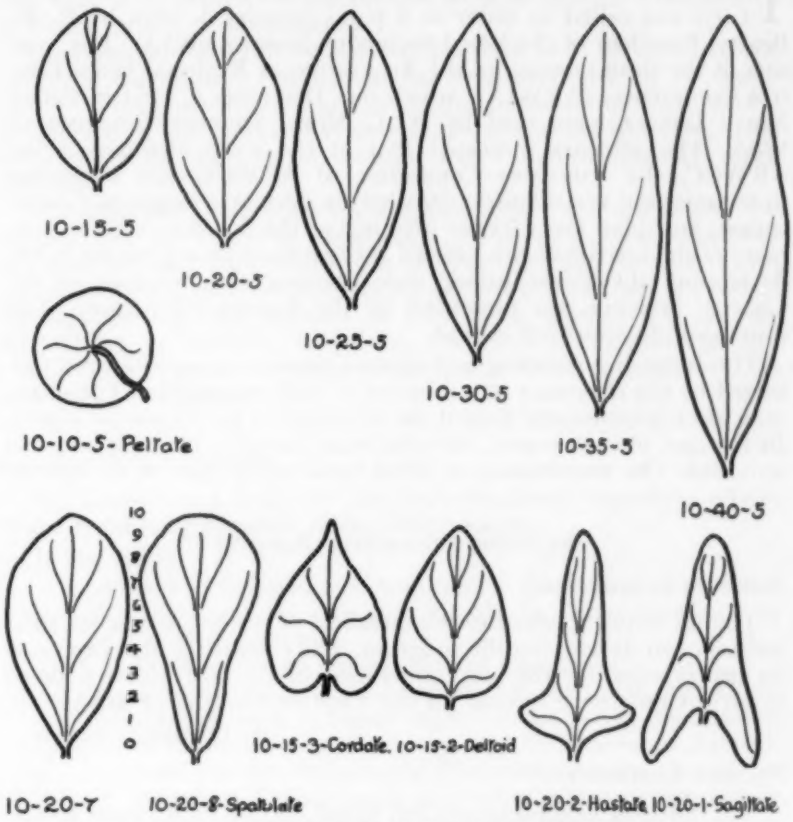

Figure 1. Examples of leaves classified under the Budd-Best system.

A peltate leaf would be represented by the formula, 10–10–5–peltate, and a cordate leaf might be, 10–15–3–cordate, the only size needed being the greatest width. In parallel margined leaves the location of the lower and upper limits of the greatest width are bracketed, as for instance, 10–40–(2–7)–oblong, 14 mm. The 14 mm. indicates the greatest width.

This system can be used for almost any shape of leaf and will give a more definite indication of shape and form than the classification generally used.

Minutes of Business Meeting, Weed Society of America, January 4, 5, 1956

THE Business Meeting, held at the New Yorker Hotel, New York City, was called to order at 4 p.m., January 4, 1956 by R. H. Beatty, President of the Weed Society of America (WSA). The minutes of the sixth meeting of the Association of Regional Weed Control Conferences (ARWCC), which met December 8, 1954 in Fargo, North Dakota, were read by W. C. Shaw, Secretary-Treasurer of WSA. The minutes indicated that at the sixth meeting of the ARWCC, the Executive Committee of ARWCC was instructed to organize the Weed Society of America, develop a tentative Constitution, and plan the Charter Meeting of the Society. A brief summary of the activity of the Executive Committee in organizing WSA, developing the Constitution, and planning the program of the Charter Meeting was presented by the Secretary-Treasurer. The minutes were approved as read.

The following standing and special committee reports were presented by the chairman or a member of each committee. The chairman of each committee moved the adoption of his respective report. In the case of each report, the chairman's motion for adoption was seconded. The membership of WSA voted acceptance of all reports.

Standing Committee Reports

Program Committee.

Thanks were expressed to the members of the committee for their assistance in developing the program. The committee also expressed its appreciation for the fine cooperation of the Northeastern Weed Control Conference as host for the Charter Meeting of WSA.

A. O. Kuhn, *Chmn.*

Finance Committee.

The Finance Committee of the Weed Society of America recommends that monies placed in the Endowment Fund be invested in municipal or government bonds. Recognizing that the interest rate on such bonds is not as high as might be available elsewhere, the Committee considers these bonds capable of returning a reasonable profit without excessive gamble.

E. G. Rodgers, *Chmn.*

Terminology Committee.

A brief description of the objectives and accomplishments of the Committee was presented. The Chairman expressed his thanks to the members of the Committee for their assistance and excellent cooperation in developing the report. The detailed report of the Committee is published in WEEDS 4 (3):278–287. 1956.

W. C. Shaw, *Chmn.*

EDITORIAL COMMITTEE.

As of January 1, 1956, WEEDS had 806 subscribers. Issue 1 of Vol. IV, the January, 1956, issue, was mailed during the last week of December. Issue 2 of Vol. IV is in the hands of the printer and should be mailed during the last week of March, 1956. Issue 3 is in the process of preparation.

Since January 1, 1955, 30 manuscripts have been reviewed by the Editorial Committee. Publication has been arranged for 16 manuscripts. Three manuscripts are awaiting publication. Four manuscripts are in the hands of reviewers. Four manuscripts have been returned to the authors for revision and 4 manuscripts have been rejected.

The Editorial Committee and the Editor will welcome additional manuscripts on research, regulatory, educational, and extension activities dealing with weeds. All will be reviewed for merit and general interest to the membership of WSA. It is our hope that the membership will respond by forwarding manuscripts and by subscribing to WEEDS. In return, the Editorial Committee will endeavor to prepare a journal of particular value to weed workers on a regular schedule.

K. P. BUCHHOLTZ, *Chmn.*

LEGISLATIVE COMMITTEE.

The Legislative Committee met and considered important phases of the regulatory program of the Weed Society.

I. Procedure
   A. Since the Legislative Committee of the Society is national in scope, special attention should be given problems of national importance.
      1. Work with the regions toward uniformity.
      2. Consider source of support for national legislation through such national organizations as the Association of Commissioners, Directors and Secretaries of Agriculture and the Agricultural Committee on the Council of Interstate Government, and other groups interested in our problems such as the industry involved.

II. Problems of National Importance
   A. Consider action to make funds available to those responsible for administering federally owned and controlled lands.
   B. Consider further regulations relative to the interstate movement of weed seed infested commodities and equipment.
   C. Work toward uniformity of regulations pertaining to pest control operations.
   D. Work toward uniformity pertaining to registration of herbicides and economic poisons. There are now federal and state representatives, but further unification may be worthy of consideration.

E. Review legislation and consider changes that may be needed for the improvement of the legulations. The Miller Bill may be one of these to be considered.

F. It was suggested that an industry member be appointed to the Legislative Committee. Industry legislative committees are very active in legislation pertaining to our weed control problems and industry is well represented in the Weed Society of America.

W. S. BALL, *Chmn.*

EDUCATION COMMITTEE.

In order that the Education Committee can develop an adequate program, the objectives and aims of the Committee need to be clarified. It is requested that the following be made a part of the objectives, aims, and duties of the committee.

1. Develop an undergraduate curriculum in Weed Control by:
   (a) Developing a list of courses that are considered important to the field and establish a rating system to indicate the desirability of the course.
   (b) Develop a list of schools offering weeds courses. Include in this list the courses taken which are directly associated with the field and the number of students taking such courses.
   (c) Encourage the use of such trained students by both commercial and governmental agencies.
2. Develop a graduate program in Weed Control along similar lines as outlined above.
3. Promote all phases of adult education such as extension and commercial educational programs and develop methods and techniques for facilitating this work.
4. Work towards a set of constitutional by-laws which will clearly establish the objectives, aims, and duties of the Education Committee.

G. C. KLINGMAN, *Chmn.*

SPECIAL COMMITTEES

CONSTITUTION AND BY-LAWS COMMITTEE.

The Constitution which had been in preparation since December 8, 1954, was read in detail and approved by the Society membership in attendance at the Charter Meeting. The Constitution as approved was published in WEEDS 4 (2):181–184, 1956.

A. O. KUHN, *Chmn.*

PUBLIC RELATIONS COMMITTEE.

The Public Relations Committee prepared three news releases that were sent to approximately 350 trade magazines, farm journals, and newspapers in all sections of the United States. Numerous articles have appeared based on these releases. One radio release was

sent to 550 radio farm directors. Personal contacts have been maintained with about 20 representatives of the press. A feature highlighting the Weed Society Charter Meeting has been scheduled for presentation on a network radio farm program. Additional releases will be prepared and distributed at the close of the meeting.

JACK DREESSEN, *Chmn.*

SUSTAINING MEMBERSHIP COMMITTEE.

More than 125 companies representing all phases of weed control, chemicals, equipment, and custom applicators, were contacted and invited to support the Weed Society of America through sustaining memberships. Through January 4, 1956, a total of 22 sustaining members have contributed to the Society.

JACK DREESSEN, *Chmn.*

MEMBERSHIP COMMITTEE.

Charter members—December 31, 1955	621
Sustaining members—December 31, 1955	20
Total subscriptions to WEEDS—December 31, 1955	806

W. C. JACOB, *Chmn.*

AUDITING COMMITTEE.

This Committee was appointed to prepare a report on the financial status of WEEDS, Volumes I to III prior to the transfer of WEEDS, journal of ARWCC to WEEDS, journal of WSA.

INCOME

Advertising	$ 5,250.00	
Subscriptions and reprints	13,166.19	
	18,416.19	
Less debit memos	85.30	
Total net income	18,330.89	$18,330.89

EXPENSES

Publications	$16,204.44	
Communications	716.72	
Miscellaneous	229.40	
Total	17,150.56	$17,150.56
Balance		1,180.33
Outstanding checks		151.82
Bank balance		1,332.15

ADDITIONAL INCOME AND EXPENSE

Income due from reprints.	$139.48	
Less additional expense....	5.00	
Income due		134.48
Balance	$1,180.33	
Income due	134.48	
	$1,314.81	

Cash on hand or due at close of Vol. III WEEDS.

E. R. MARSHALL, *Chmn.*

WSA FINANCIAL REPORT, JANUARY 1, 1956.

RECEIPTS

Memberships and subscriptions to WEEDS	$4,480.39	
Sustaining memberships	2,000.00	
Advertising in Volume IV	600.00	
TOTAL		$7,080.39

EXPENDITURES

Stationery and supplies	$ 131.20	
Mimeographing	11.85	
Postage and Telephone	263.54	
Office equipment	111.48	
Secretarial labor	321.00	
Travel of Bus. Mgr.	213.43	
Bank charge	.25	
TOTAL EXPENDITURES		$1,052.75
Cash on Hand		6,027.64
TOTAL		$7,080.39

W. C. JACOB, *Business Manager*

AUTHOR AND SUBJECT-TITLE INDEX VOLUME IV, 1956

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News and Notes

The program has been announced for the North Central Weed Control Conference scheduled to be held December 10, 11 and 12, 1956 at the Sherman Hotel, Chicago. It will include sectional programs on Field Crops, Botany and Plant Physiology, Industrial Weed Control, Turf, Weeds, Horticulture, Regulatory and Extension, and Water Weeds and Weed Control in Wildlife Habitats.

Marion W. Parker, who has served as head of the Weed Investigations Section, ARS, USDA, since 1954, has been appointed assistant director of the U. S. Department of Agriculture's Agricultural Research Service.

Edward B. Hollingsworth was recently appointed plant physiologist with the Weed Investigations Section, USDA, and will be stationed at Purdue University Agricultural Experiment Station, Lafayette, Indiana. He will carry out research in weed control with particular emphasis on problems in forage crops and pastures. Hollingsworth was formerly with the Department of Plant Pathology and Physiology, Mississippi State College.

Weed Abstracts is a mimeographed publication that can be obtained from the British Weed Control Council, Cecil Chambers, 86 Strand, London, W. C. 2. England. This publication is prepared fortnightly by the Information Section, Unit of Experimental Agronomy, University Department of Agriculture, Agricultural Research Council, Oxford, England. Short abstracts are given on articles dealing with all phases of weed control. Charges are 2 pounds and 2 shillings per annum.

Anson R. Cooke has accepted a position with the Chemical Dept., Experimental Station, E. I. DuPont de Nemours and Co., Wilmington, Delaware, where he will do fundamental work on plant growth and growth hormones. He was formerly a member of the Botany and Plant Pathology Dept., Oklahoma A. & M. College, Stillwater, Oklahoma.

The Recommendations Committee of the British Weed Control Council has prepared a booklet entitled "Weed Control Handbook 1956". This handbook classifies all weedkillers in common use in Great Britain and sets out the agricultural and horticultural crops on which each type of herbicide can safely be used, at the same time indicating the weeds which can be controlled by each type of chemical. Copies can be purchased from the British Weed Control Council, Cecil Chambers, 86 Strand, London, W. C. 2 at a cost of 5 shillings per copy.

Charles R. Gunn, Ross Seed Company, P. O. 1713, Louisville 1, Kentucky, is interested in obtaining information about *Aegilops cylindrica* Host, especially its occurrence in the eastern and middle parts of the United States. Any personal observation or literature citation will be of interest to him.

Abstracts of the papers presented at the New York City meeting of the Weed Society of America, January 4–5, 1956 are available in mimeographed form. The abstracts may be obtained from Walter Jacob, Dept. of Agronomy, Univ. of Illinois, Urbana, Illinois, for $1.00 per copy. Checks should be made payable to the Weed Society of America.

Mark Wiltse has taken a position as field specialist with the Dow Chemical Company and will be located in Washington, D. C.

Earnest R. Marshall, who was formerly with GLF, has assumed a new position with Carbide and Carbon Chemicals Co., where he will be responsible for agricultural chemicals including herbicides.

Alan Kates assumed a position in weed control extension with the Virginia Agricultural Experiment Station in June 1956.

The Second Cornell Weed Day was held on July 19, 1956. The tour and discussions were conducted jointly by the Departments of Agronomy and Vegetable Crops at Cornell University.

Marvin M. Schreiber, formerly with the Agronomy Department, Cornell University, Ithaca, New York, was appointed as agronomist with the Weed Investigations Section, USDA. Schreiber will conduct research pertaining to the control of weeds in pastures and the establishment of forage crops for new pastures. He will be stationed at Ithaca, New York, and his studies will be conducted in cooperation with Cornell University.

William B. Ennis, Jr. succeeded Marion W. Parker as the Head of the Weed Investigations Section, USDA, on July 1, 1956. Formerly stationed at State College, Mississippi, with the Weed Investigations Section, he was transferred to Beltsville in January of 1956.

Donald A. Schallock was appointed Extension Weed Specialist at Rutgers University in July 1956. Formerly Extension Specialist responsible for corn and small grains at Rutgers, Schallock is filling a position just established to coordinate all weed control extension at the New Jersey Agricultural Experiment Station.

Erratum

Volume IV:

Page 285, the first sentence in section 3.3 of Appendix A, *A Common Name shall be preferably short and need have no chemical name or nature of the product,* should read, *A Common Name shall be preferably short and need have no chemical significance in itself, nor have any relationship to the chemical name or nature of the product.*

SUSTAINING MEMBERS

American Chemical Paint Company, Ambler, Pennsylvania
American Cyanamid Company, New York, New York
American Smelting and Refining Company, So. Plainfield, New Jersey
Association of American Railroads, Chicago, Illinois
John Bean Division, Food Machinery & Chemical Corp., Lansing, Michigan
Carbide and Carbon Chemicals Company, New York, New York
Chipman Chemical Company, Inc., Bound Brook, New Jersey
The Dow Chemical Company, Midland, Michigan
E. I. duPont de Nemours & Co., Inc., Wilmington, Delaware
The Engine Parts Manufacturing Company, Cleveland, Ohio
G.L.F. Soil Building Service, Ithaca, New York
Hercules Powder Company, Wilmington, Delaware
Monsanto Chemical Company, St. Louis, Missouri
National Aluminate Corp., Chicago, Illinois
Oberdorfer Foundries, Inc., Syracuse, New York
Olin Mathieson Chemical Company, Baltimore, Maryland
Penn Line Service, Inc., Scottdale, Pennsylvania
Pittsburgh Coke & Chemical Company, Pittsburgh, Pennsylvania
O. M. Scott and Sons Company, Marysville, Ohio
Spraying Systems Company, Bellwood, Illinois
Standard Agricultural Chemicals, Inc., Hoboken, New Jersey
Swift and Company (Plant Food Division), Chicago, Illinois

Time to Renew Your Membership

This, the last issue of Volume IV of WEEDS, signifies the end of the volume and also the end of the membership year. Those of you who have not renewed your membership or subscription should do so at once to avoid unnecessary delay in receiving the first issue of Volume V. The first issue will be mailed early in January and it will be sent only to those who have renewed. Be on time this year, renew your membership in the Weed Society of America now.

To make it easy for you the blank is included below and it is only necessary for you to clip the form, fill it out and send it along with your check to **Dr. W. C. Jacob, Treas-Business Manager, Department of Agronomy, University of Illinois, Urbana, Illinois.**

- -

WEED SOCIETY OF AMERICA

Application for Membership

Membership in the Society shall be open to individuals and organizations of all nations interested in the objectives of the Society.

I. ***Active Membership.*** Active members are individuals who are interested in weeds or their control and who have remitted their annual dues to the treasurer. Active members may attend all Society meetings, vote on all matters pertaining to the Society, and hold office. The active membership fee includes a subscription to one volume of WEEDS. $6.........——

II. ***Sustaining Membership.*** Sustaining members shall consist of persons or organizations who contribute $100 or more annually for the permanent support of the Society. The names of such members shall be printed in all issues of the official publication of the Society and in the programs of regular meetings. The sustaining membership fee includes a subscription to one volume of WEEDS. $100.........——

Check the type of membership you desire, make your remittance payable to the WEED SOCIETY OF AMERICA, and return your membership dues and this application form to **Dr. W. C. Jacob, Department of Agronomy, University of Illinois, Urbana, Illinois.**

Name ....

Organization ....

Complete Mailing Address ....

Street

....

City Zone State

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
January, February, March, 1956

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Prepared By
UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Field Crops Research Branch

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Field Crops Research Branch, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

Beltsville, Maryland

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